Cassandra: How it works and what it's good for!

Christopher Batey
Technical Evangelist for Apache Cassandra
@chbatey

Who am I?

- Technical Evangelist for Apache Cassandra
  - Founder of Stubbed Cassandra
  - Help out Apache Cassandra users
- DataStax
  - Builds enterprise ready version of Apache Cassandra
- Previous: Cassandra backed apps at BSkyB

Overview

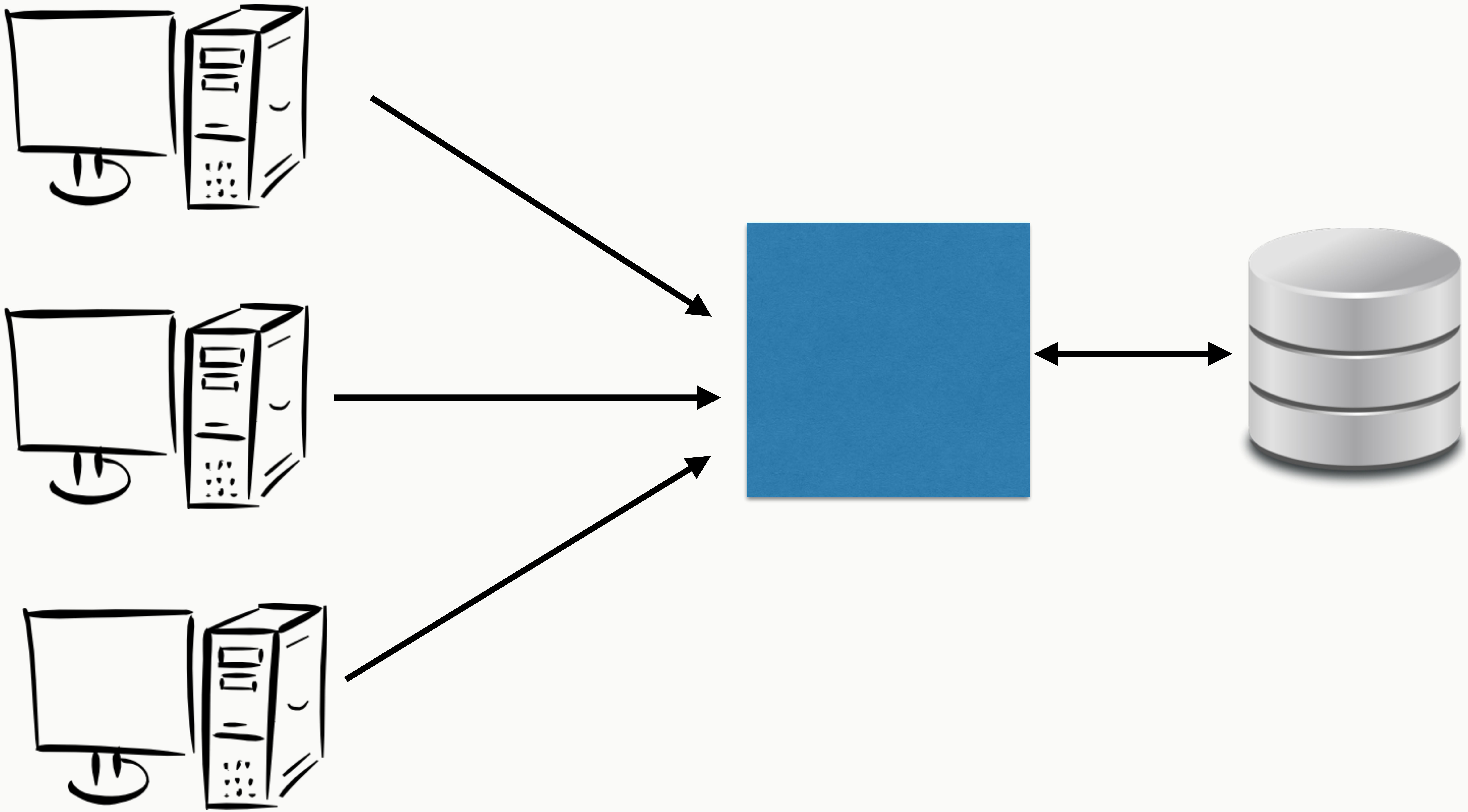
- Distributed databases: What and why?
- Cassandra use cases
- Replication
- Fault tolerance
- Read and write path
- Data modelling
- Java Driver

Distributed databases

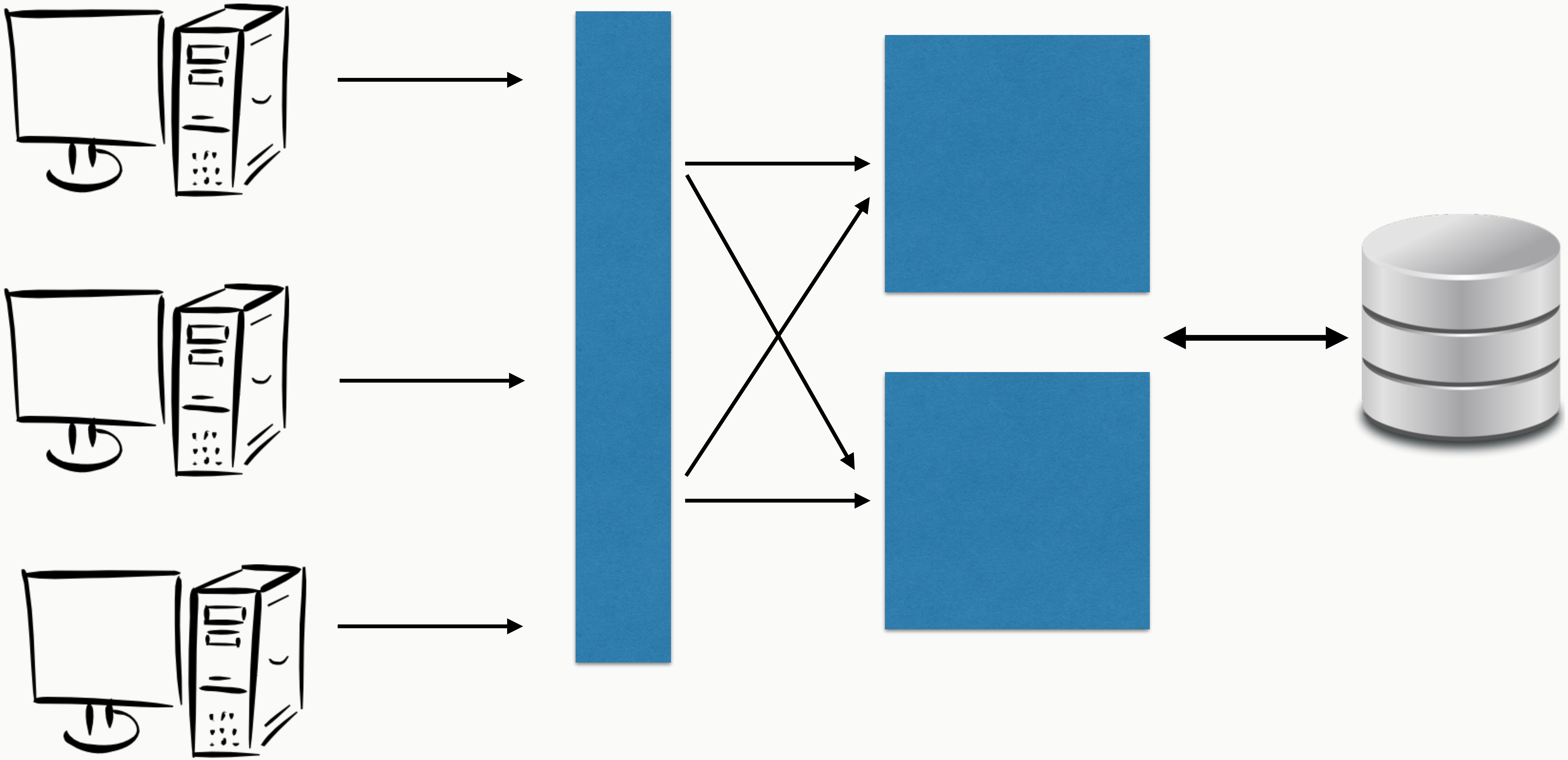
It is a big world

- Relational
  - Oracle, PostgreSQL
- Graph databases
  - Neo4J, InfoGrid, Titan
- Key value
  - DynamoDB
- Document stores
  - MongoDB, Couchbase
- Columnar aka wide row
  - Cassandra, HBase

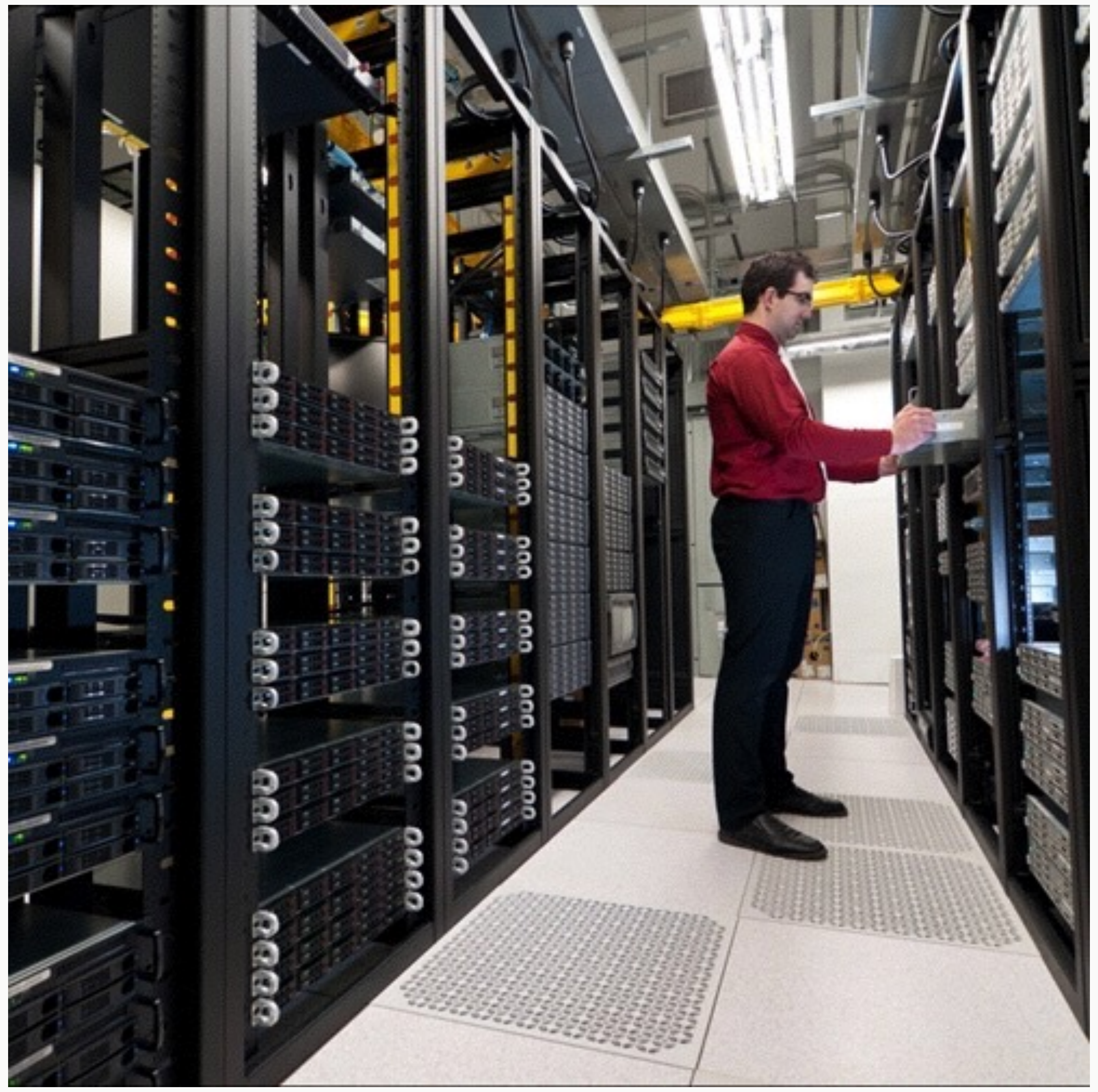
Building a web app



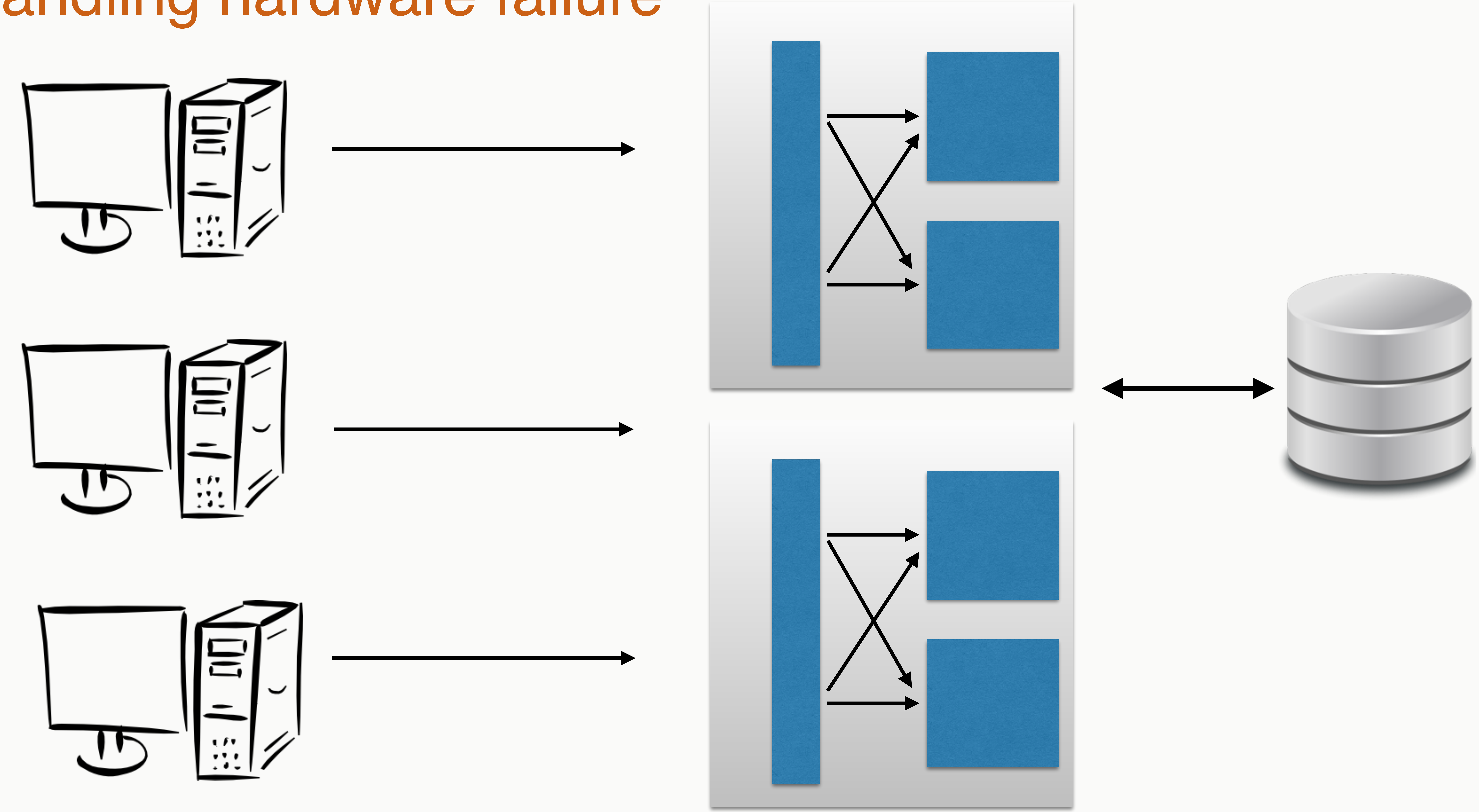
Running multiple copies of your app



Still in one DC?



Handling hardware failure



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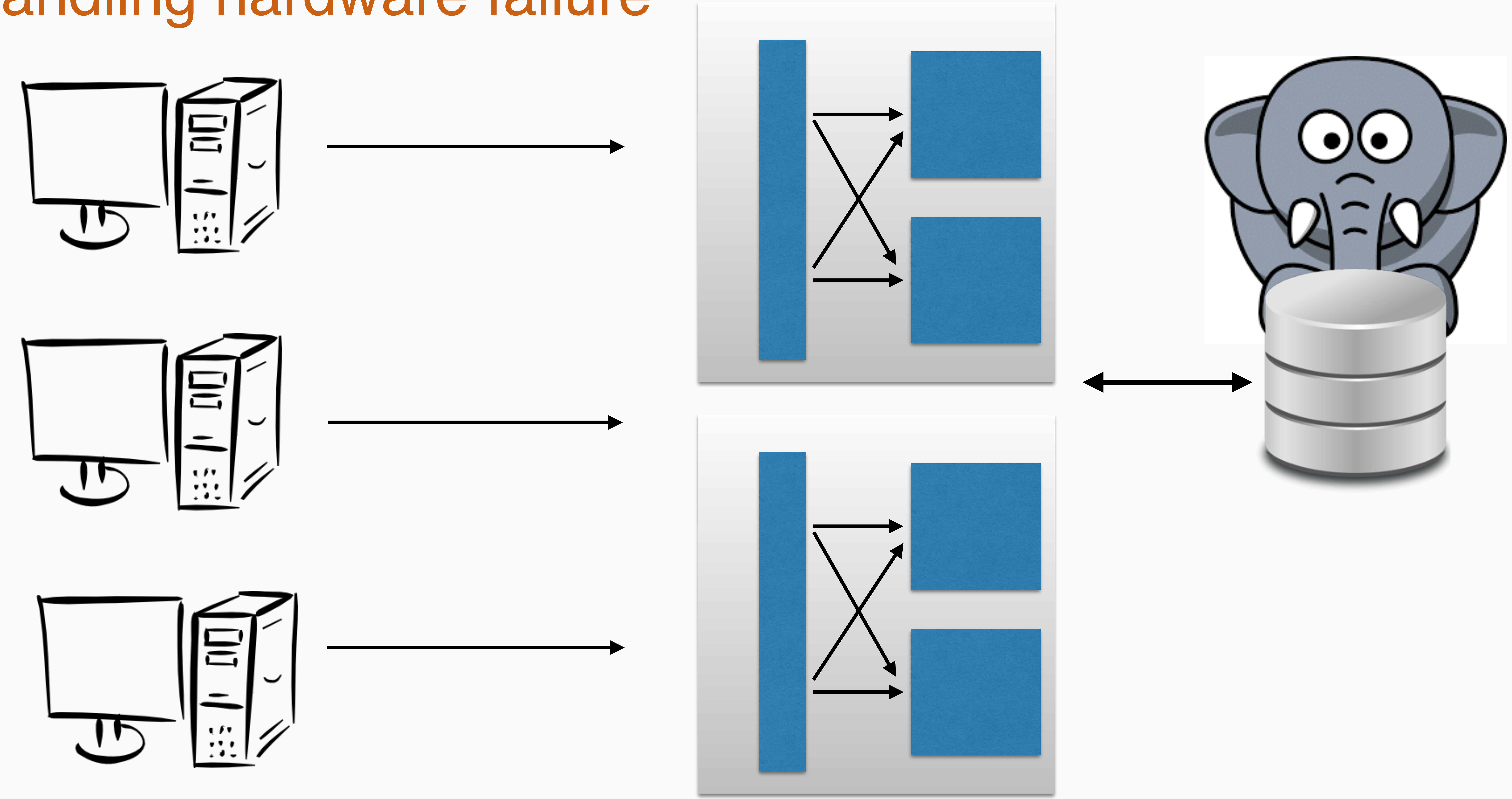
Handling hardware failure



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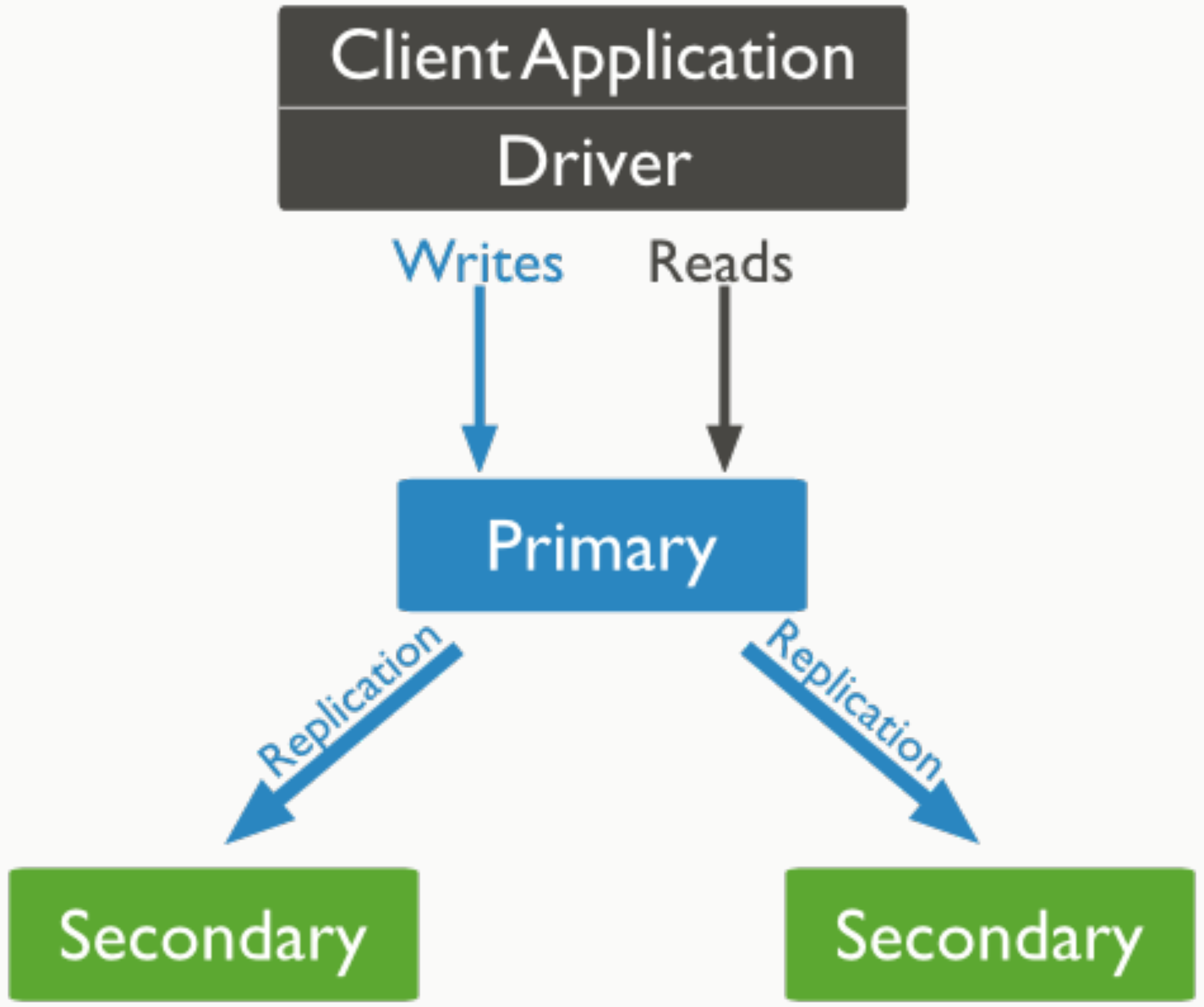
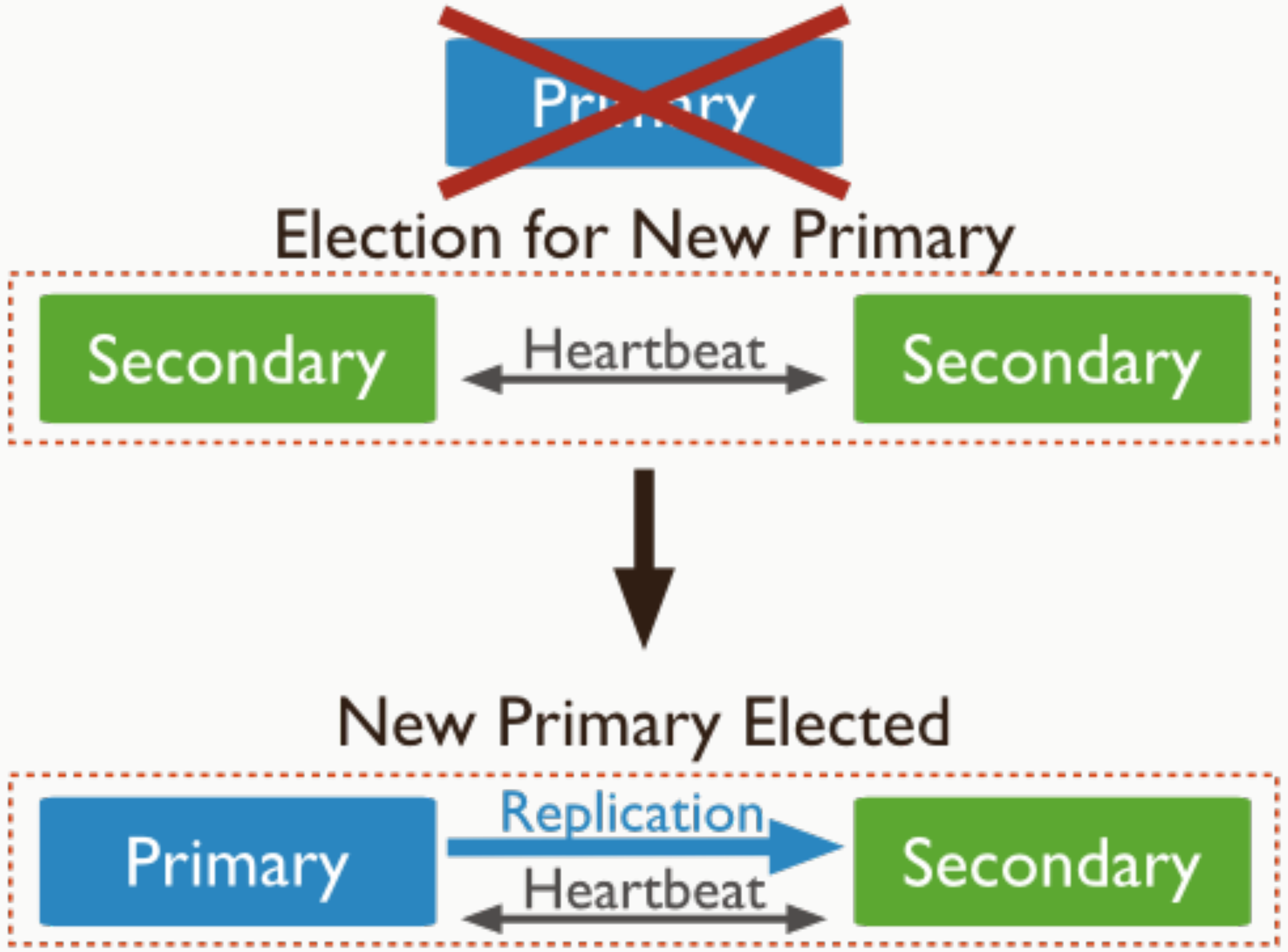
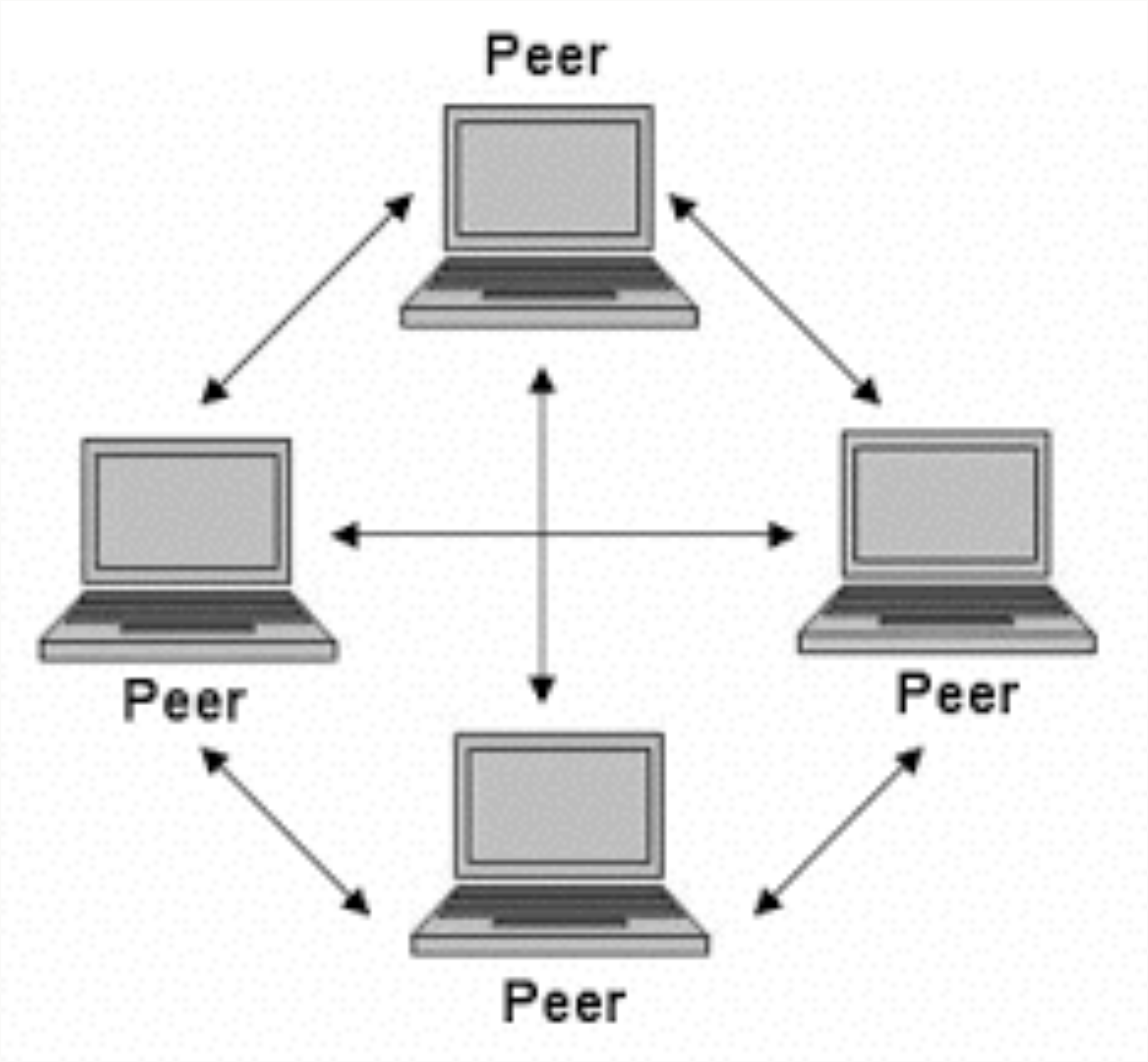
Master/slave





- Master serves all writes
- Read from master and optionally slaves

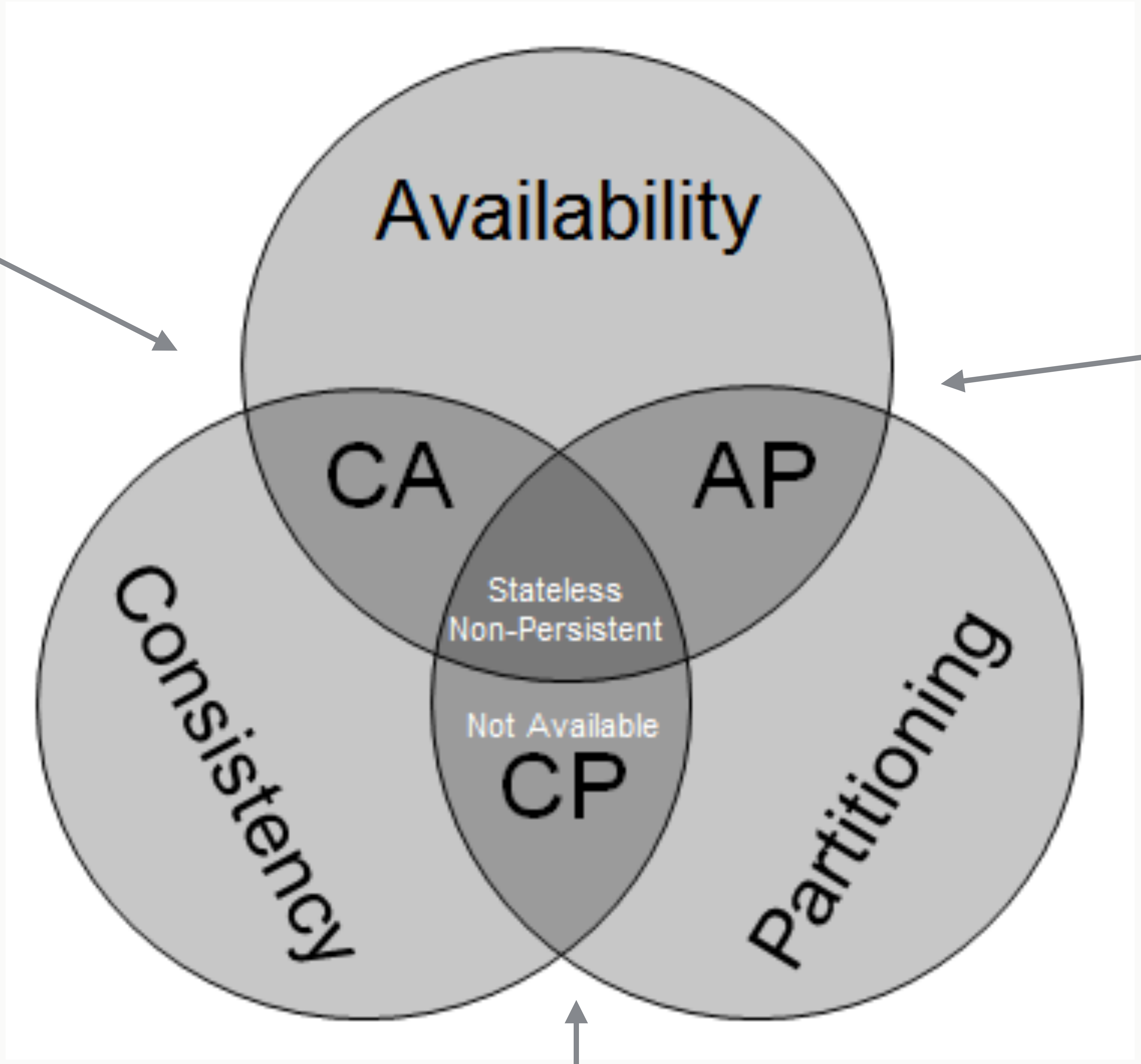
Peer-to-Peer



- No master
- Read/write to any
- Consistency?

Decisions decisions… CAP theorem

Relational Database



Highly Available Databases: Voldermort, Cassandra

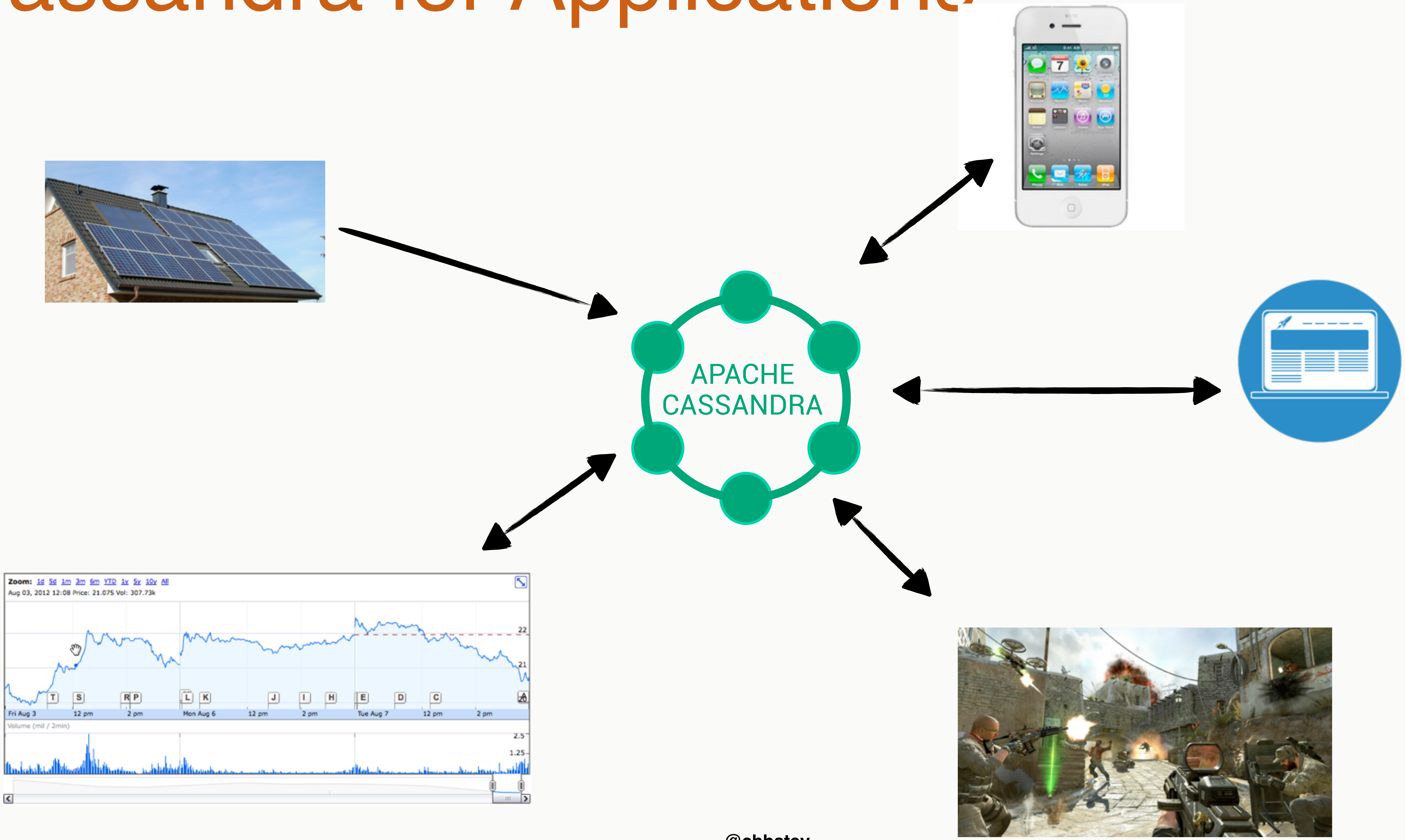
Are these really that different??

Mongo, Redis

Cassandra use cases

Cassandra for Applications

DATASTAX

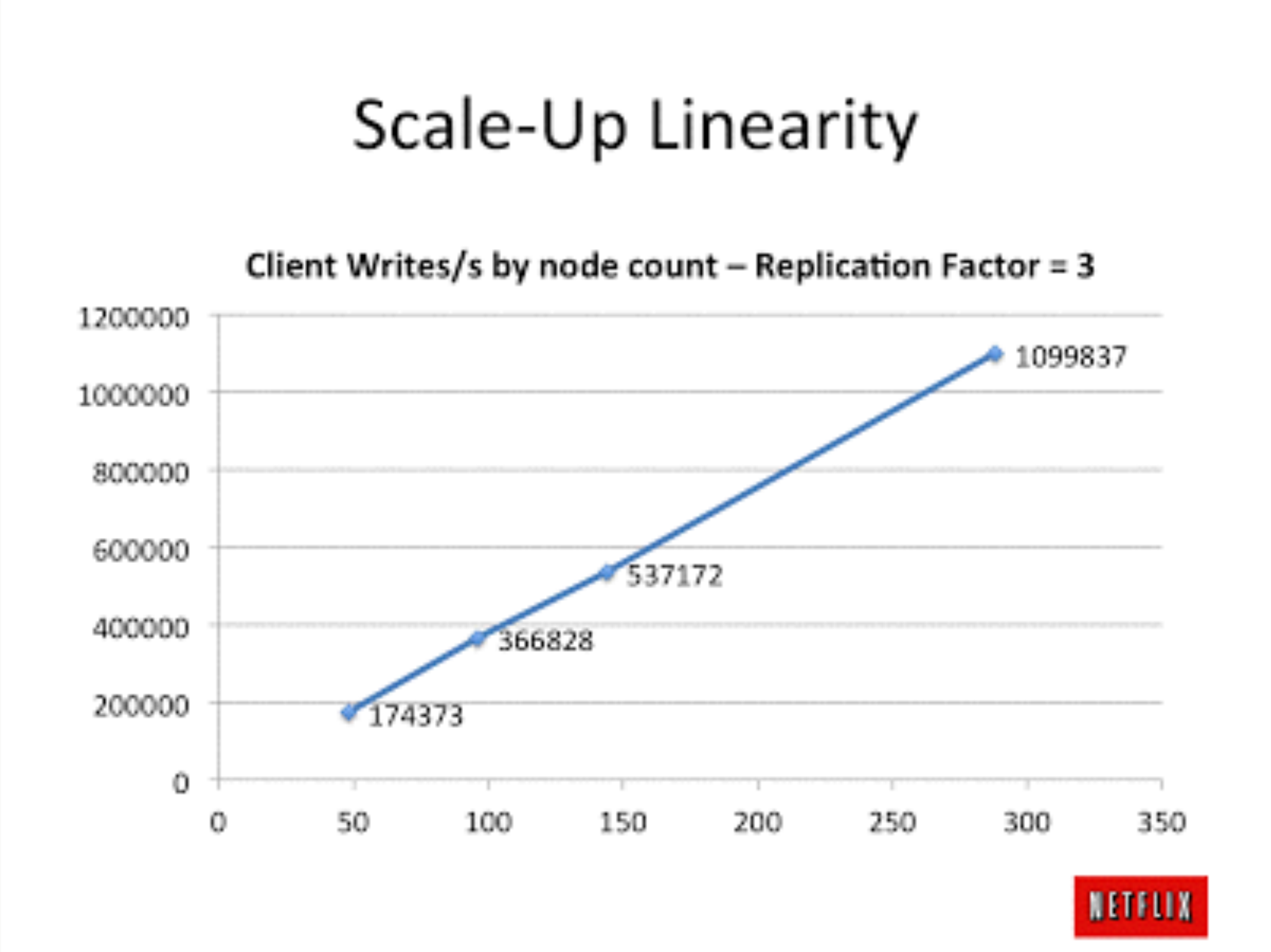


Common use cases

- Ordered data such as time series
    - Event stores
    - Financial transactions
    - Sensor data e.g IoT

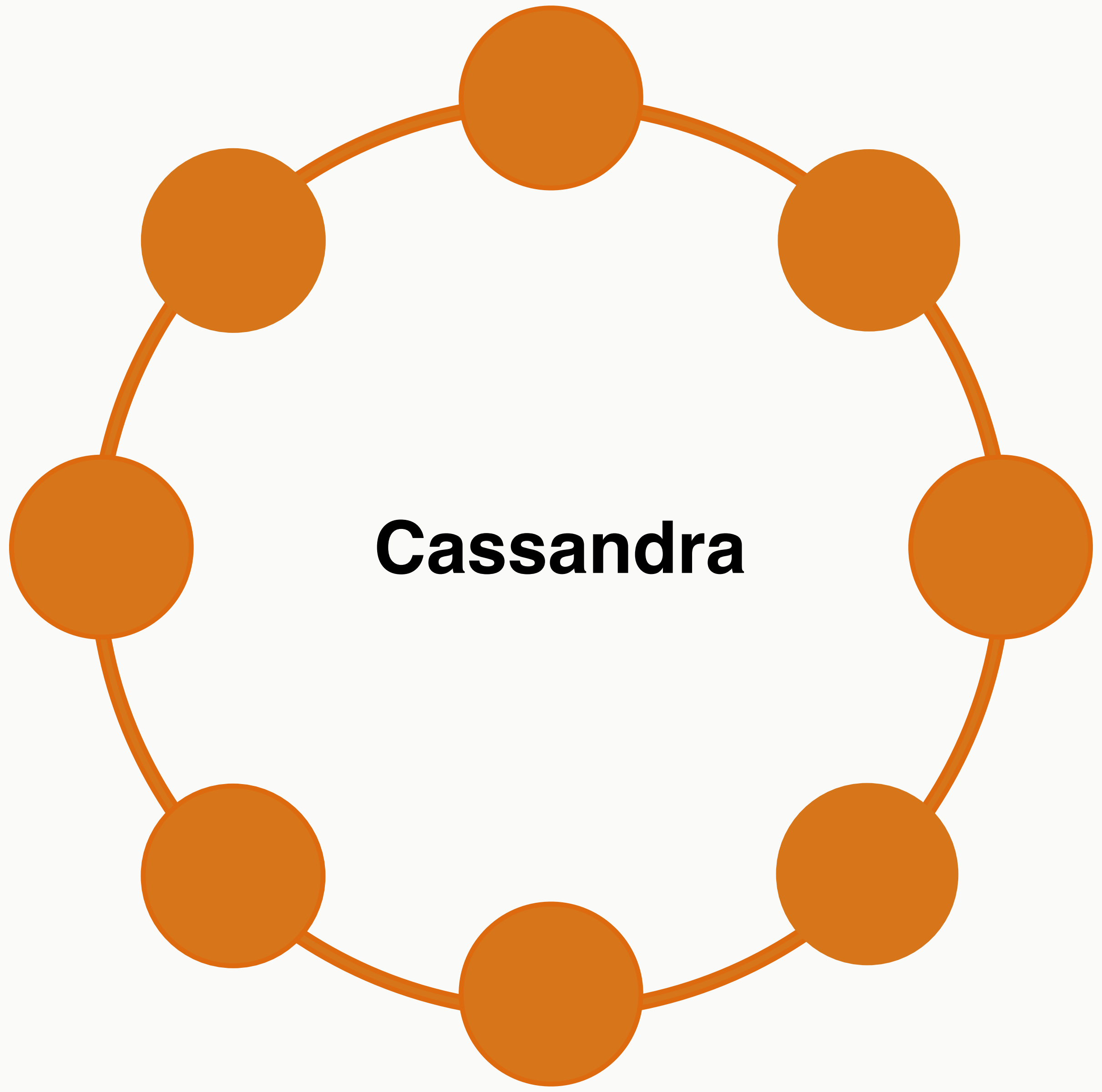
Common use cases

- Ordered data such as time series
  - Event stores
  - Financial transactions
  - Sensor data e.g IoT
- Non functional requirements:
  - Linear scalability
  - High throughput durable writes
  - Multi datacenter including active-active
  - Analytics without ETL



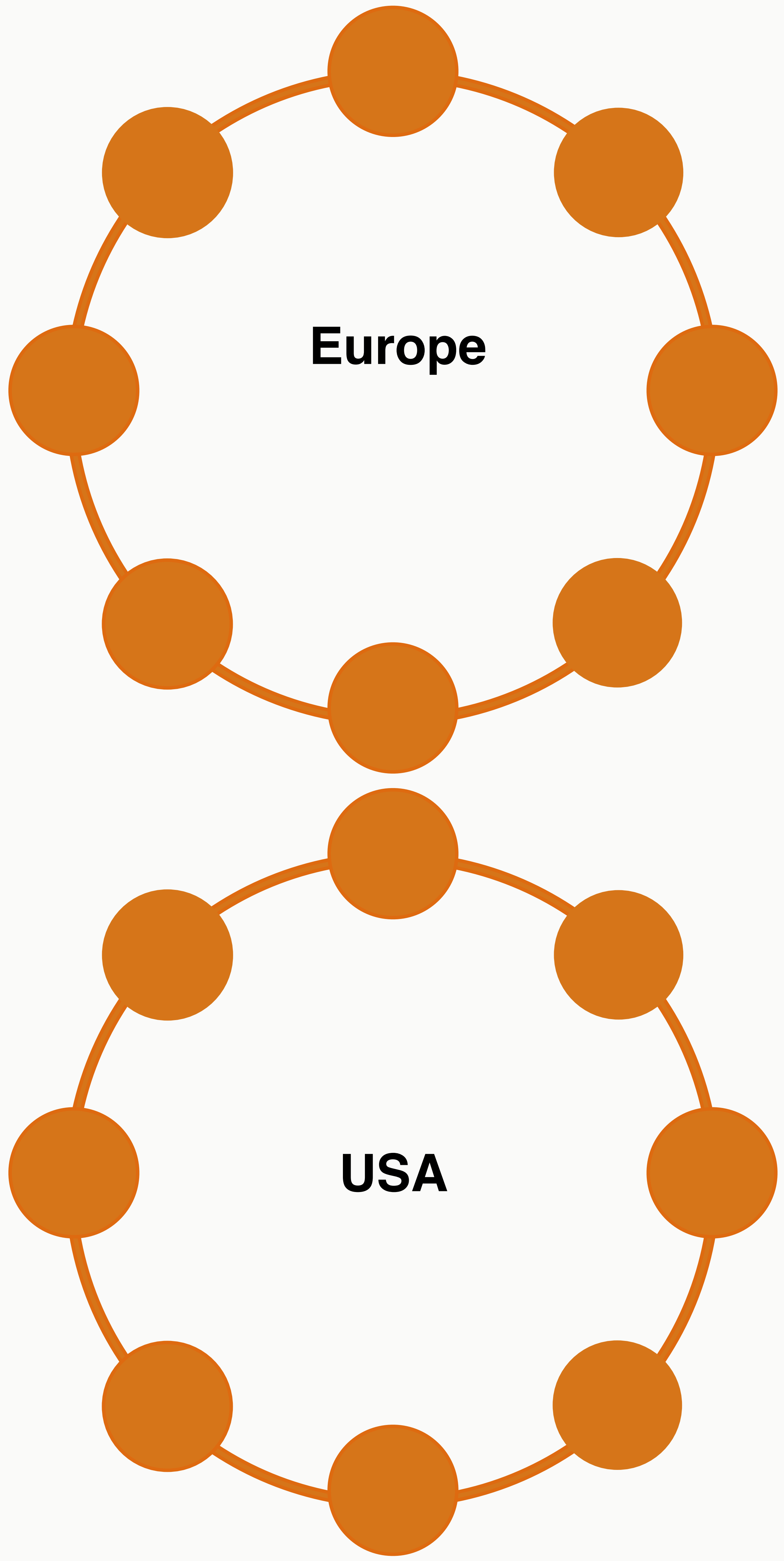
Cassandra deep dive

Cassandra



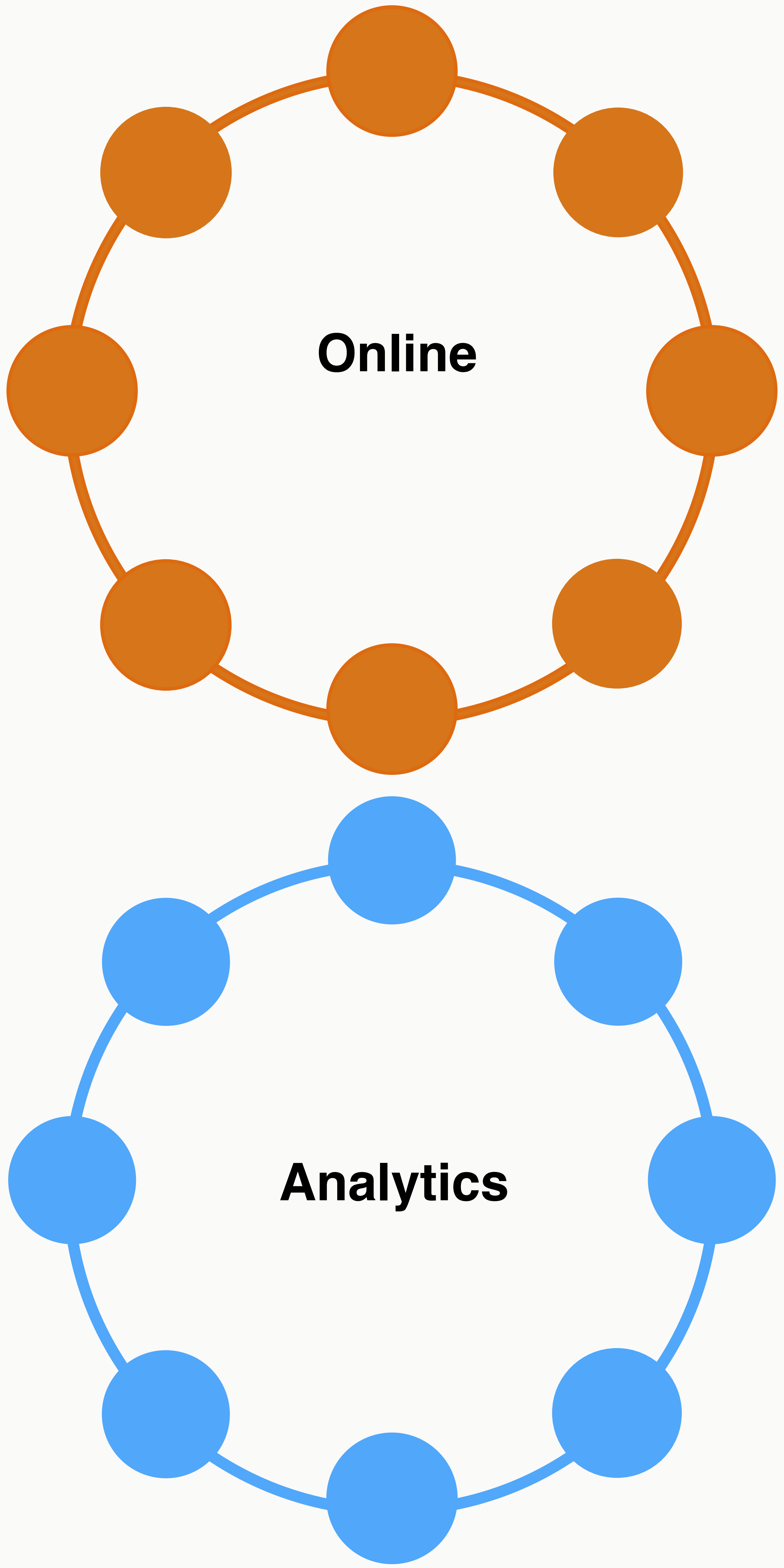
- Distributed masterless database (Dynamo)
- Column family data model (Google BigTable)

Datacenter and rack aware



- Distributed master less database (Dynamo)
- Column family data model (Google BigTable)
- Multi data centre replication built in from the start

Cassandra



- Distributed master less database (Dynamo)
- Column family data model (Google BigTable)
- Multi data centre replication built in from the start
- Analytics with Apache Spark

Dynamo 101

Dynamo: Amazon's Highly Available Key-value Store

Giuseppe DeCandia, Deniz Hastorun, Madan Jampani, Gunavardhan Kakulapati, Avinash Lakshman, Alex Pilchin, Swaminathan Sivasubramanian, Peter Vosshall and Werner Vogels

Amazon.com

ABSTRACT

Reliability at massive scale is one of the biggest challenges we face at Amazon.com, one of the largest e-commerce operations in the world; even the slightest outage has significant financial consequences and impacts customer trust. The Amazon.com platform, which provides services for many web sites worldwide, is implemented on top of an infrastructure of tens of thousands of servers and network components located in many datacenters around the world. At this scale, small and large components fail continuously and the way persistent state is managed in the face of these failures drives the reliability and scalability of the software systems.

This paper presents the design and implementation of Dynamo, a highly available key-value storage system that some of Amazon's core services use to provide an "always-on" experience. To achieve this level of availability, Dynamo sacrifices consistency under certain failure scenarios. It makes extensive use of object versioning and application-assisted conflict resolution in a manner that provides a novel interface for developers to use.

One of the lessons our organization has learned from operating Amazon's platform is that the reliability and scalability of a system is dependent on how its application state is managed. Amazon uses a highly decentralized, loosely coupled, service oriented architecture consisting of hundreds of services. In this environment there is a particular need for storage technologies that are always available. For example, customers should be able to view and add items to their shopping cart even if disks are failing, network routes are flapping, or data centers are being destroyed by tornados. Therefore, the service responsible for managing shopping carts requires that it can always write to and read from its data store, and that its data needs to be available across multiple data centers.

Dealing with failures in an infrastructure comprised of millions of components is our standard mode of operation; there are always a small but significant number of server and network components that are failing at any given time. As such Amazon's software systems need to be constructed in a manner that treats failure handling as the normal case without impacting availability or performance.

Dynamo 101

- The parts Cassandra took
  - Consistent hashing
  - Replication
  - Strategies for replication
  - Gossip
  - Hinted handoff
  - Anti-entropy repair
- And the parts it left behind
  - Key/Value
  - Vector clocks

Picking the right nodes

- You don't want a full table scan on a 1000 node cluster!
- Dynamo to the rescue: Consistent Hashing
- Then the replication strategy takes over:
  - Network topology
  - Simple

Murmer3 Example

Primary Key

- **Data:**

jim	age: 36	car: ford	gender: M
carol	age: 37	car: bmw	gender: F
johnny	age: 12	gender: M	
suzy:	age: 10	gender: F	

- **Murmer3 Hash Values:**

Primary Key	Murmur3 hash value
jim	350
carol	998
johnny	50
suzy	600

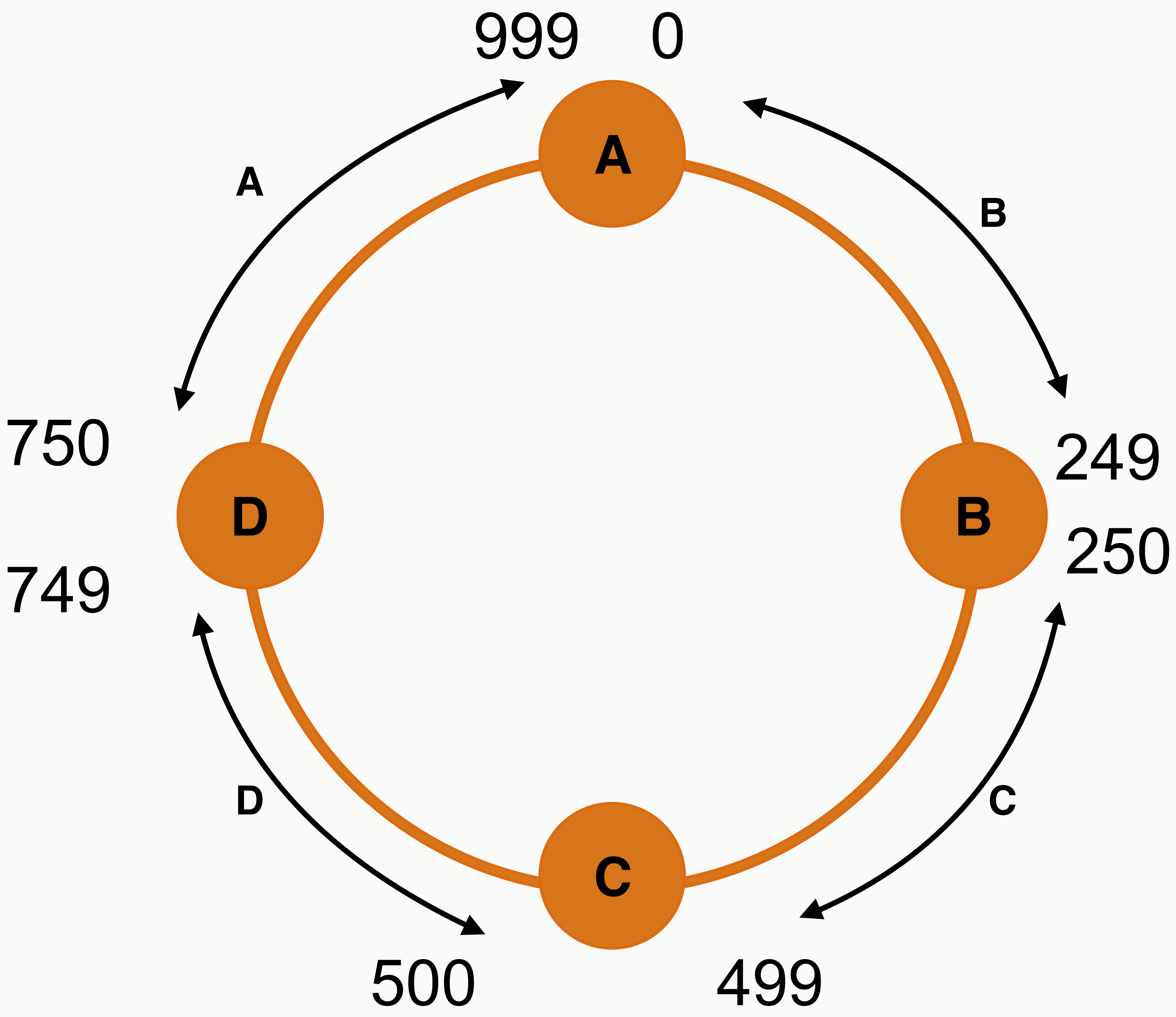
Real hash range: -9223372036854775808 to 9223372036854775807

Murmer3 Example

Four node cluster:

Node	Murmur3 start range	Murmur3 end range
A	0	249
B	250	499
C	500	749
D	750	999

Pictures are better



Murmer3 Example

Data is distributed as:

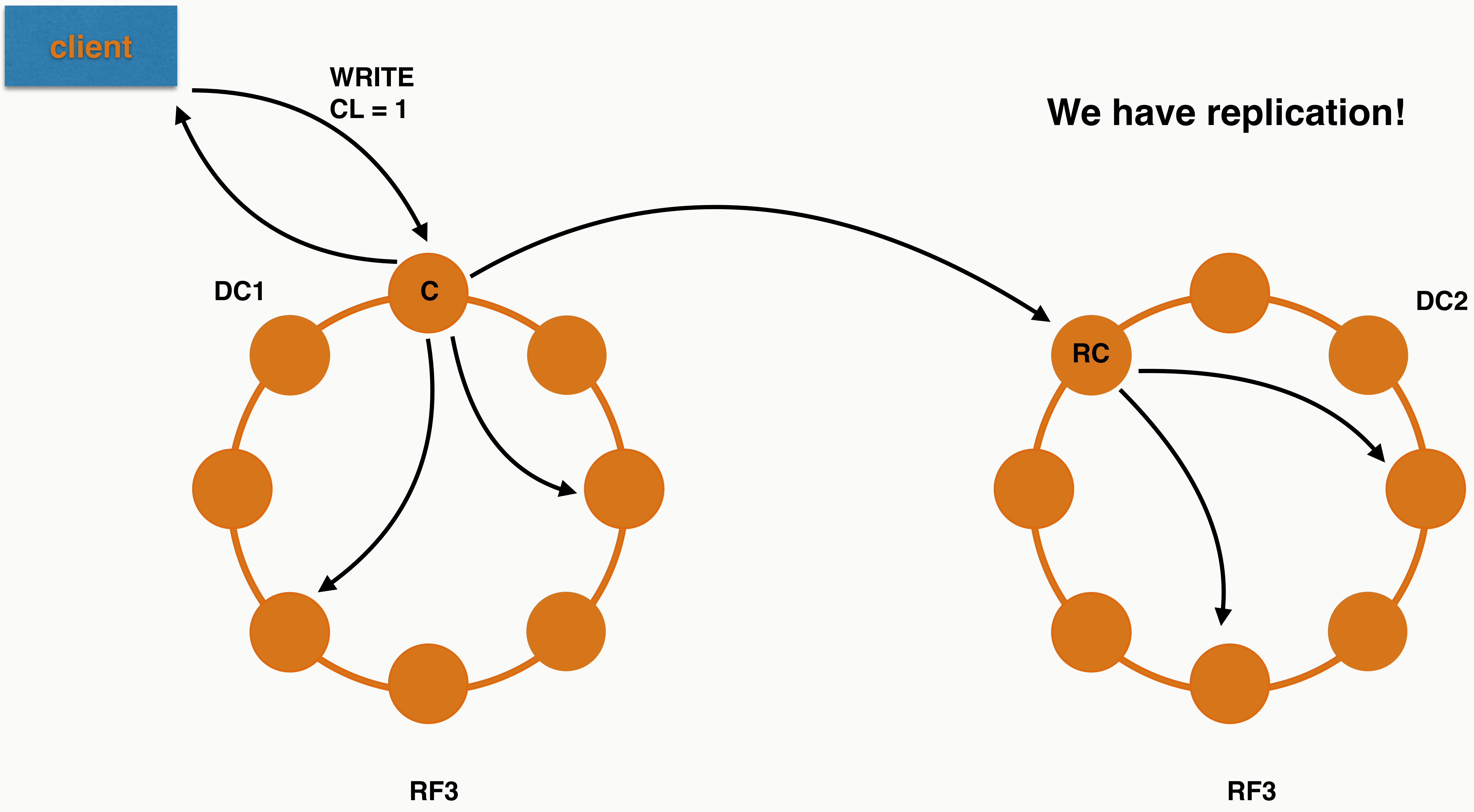
Node	Start range	End range	Primary key	Hash value
A	0	249	johnny	50
B	250	499	jim	350
C	500	749	suzy	600
D	750	999	carol	998

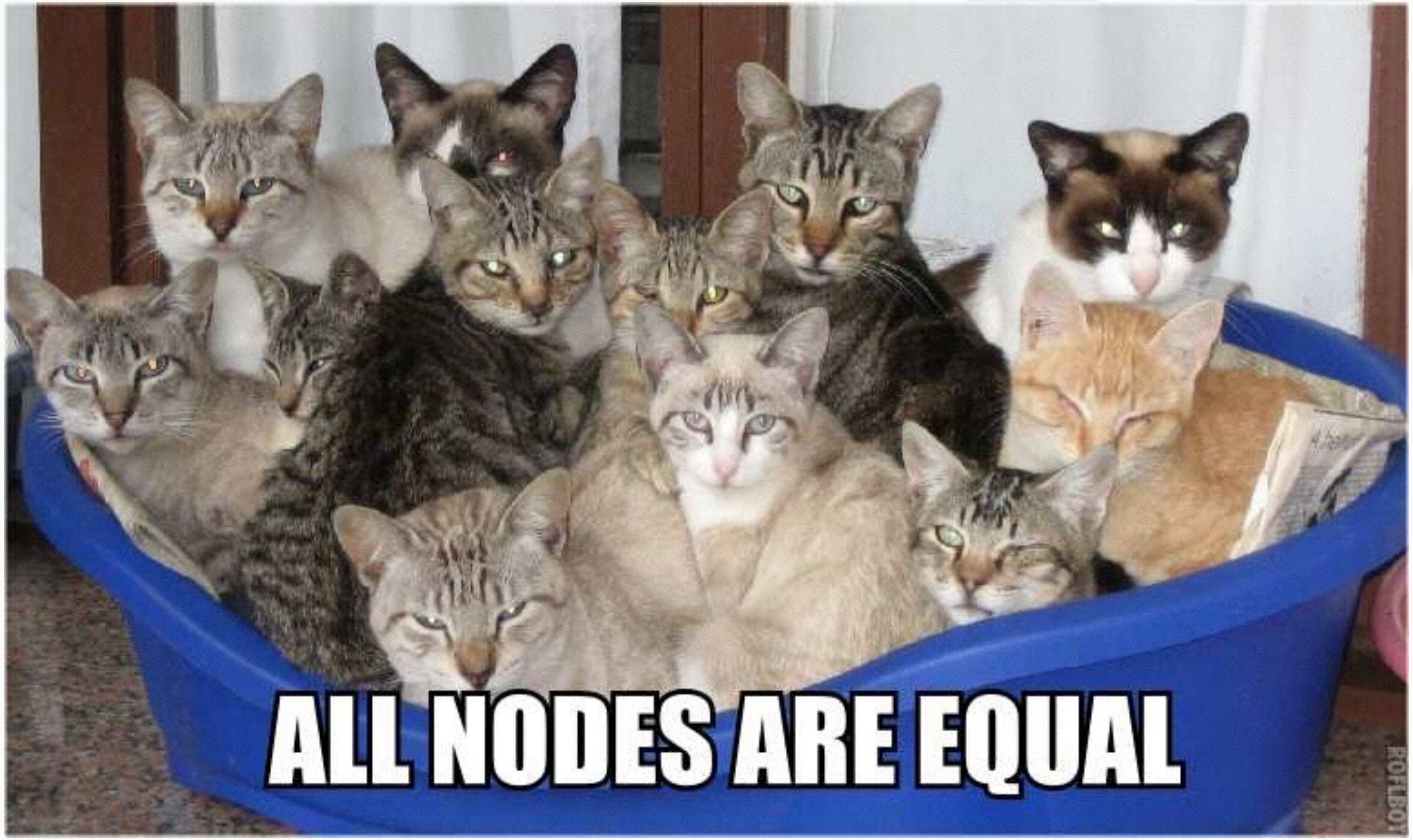
Replication

Replication strategy

- Simple
  - Give it to the next node in the ring
  - Don’t use this in production
- NetworkTopology
  - Every Cassandra node knows its DC and Rack
  - Replicas won’t be put on the same rack unless Replication Factor > # of racks
  - Unfortunately Cassandra can’t create servers and racks on the fly to fix this :(

Replication

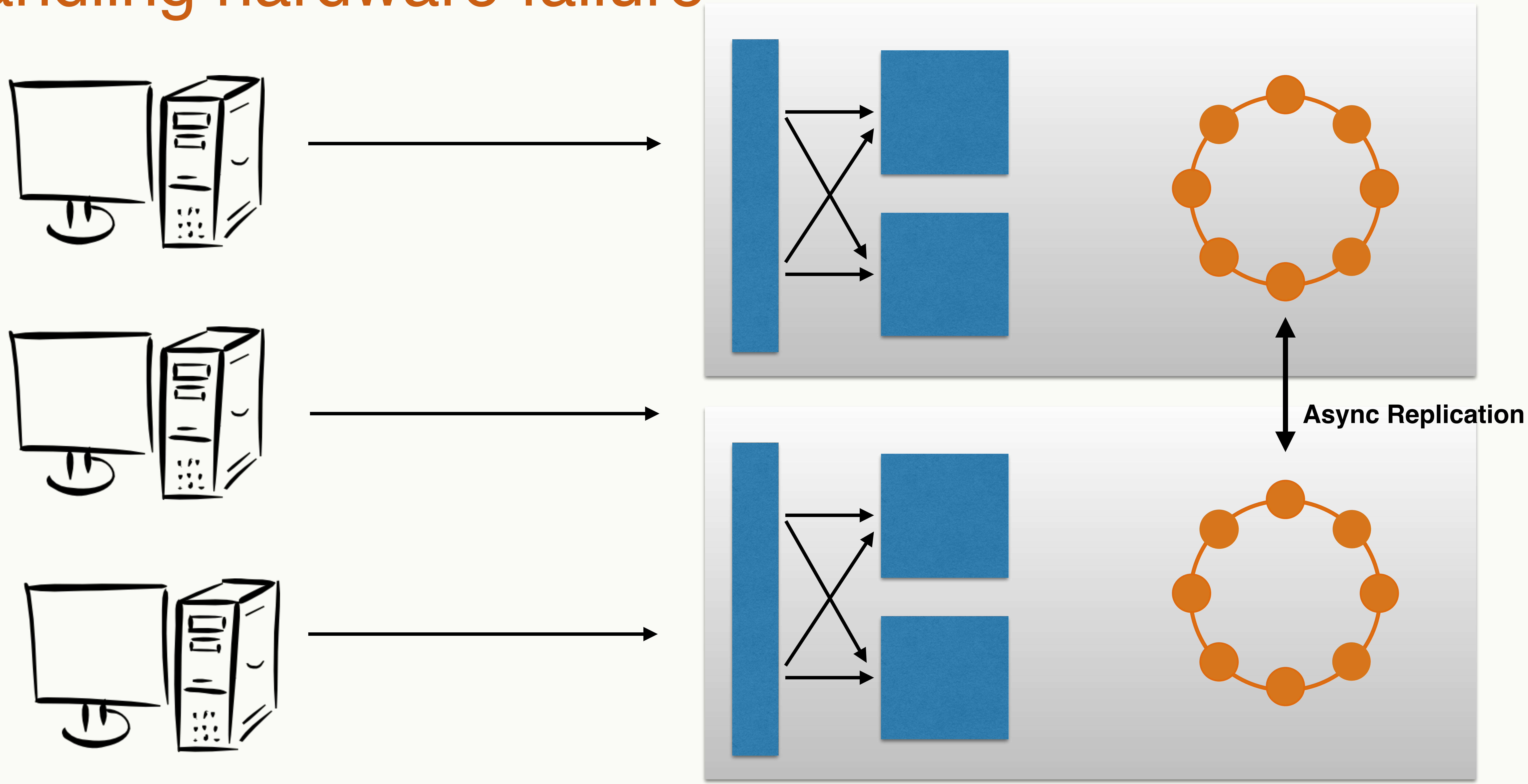



ALL NODES ARE EQUAL
ROFLBOT

Tunable Consistency

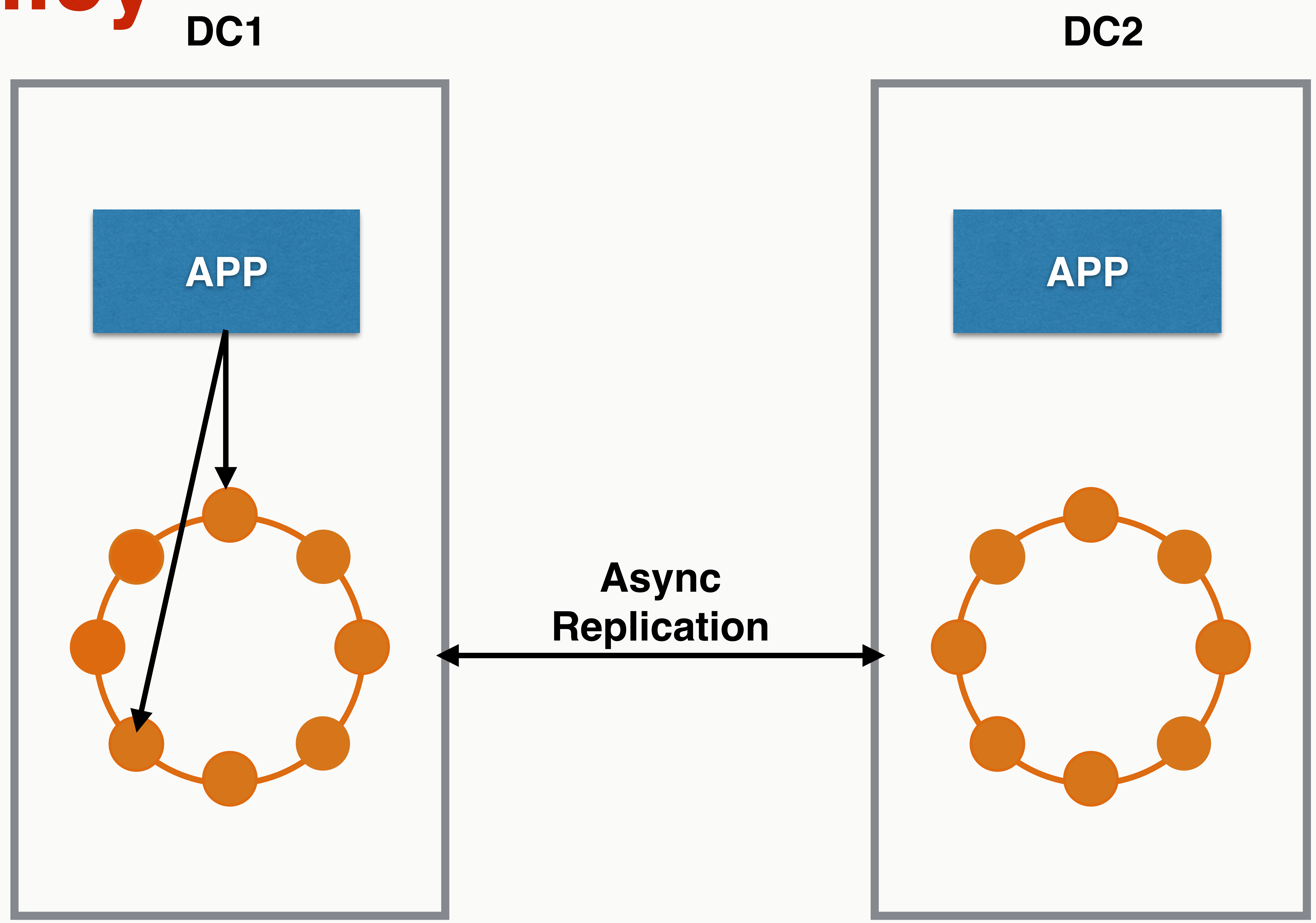
- Data is replicated N times
- Every query that you execute you give a consistency
  - ALL
  - QUORUM
  - LOCAL_QUORUM
  - ONE
- **Christos Kalantzis** Eventual Consistency != Hopeful Consistency: http://youtu.be/A6qzx_HE3EU?list=PLqcm6qE9lgKJzVvwHprow9h7KMpb5hcUU

Handling hardware failure

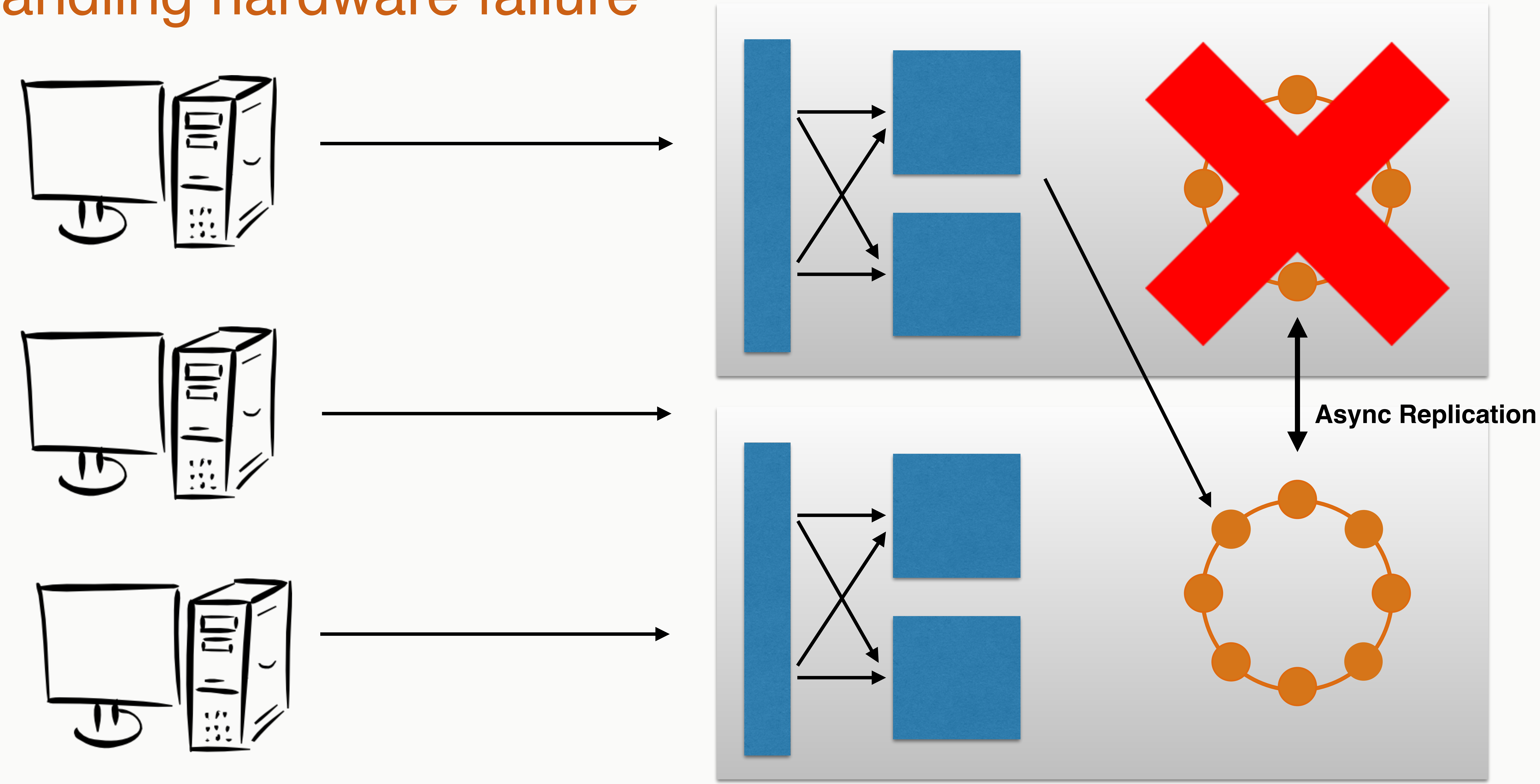


Load balancing

- **Data centre aware policy**
- Token aware policy
- Latency aware policy
- Whitelist policy



Handling hardware failure



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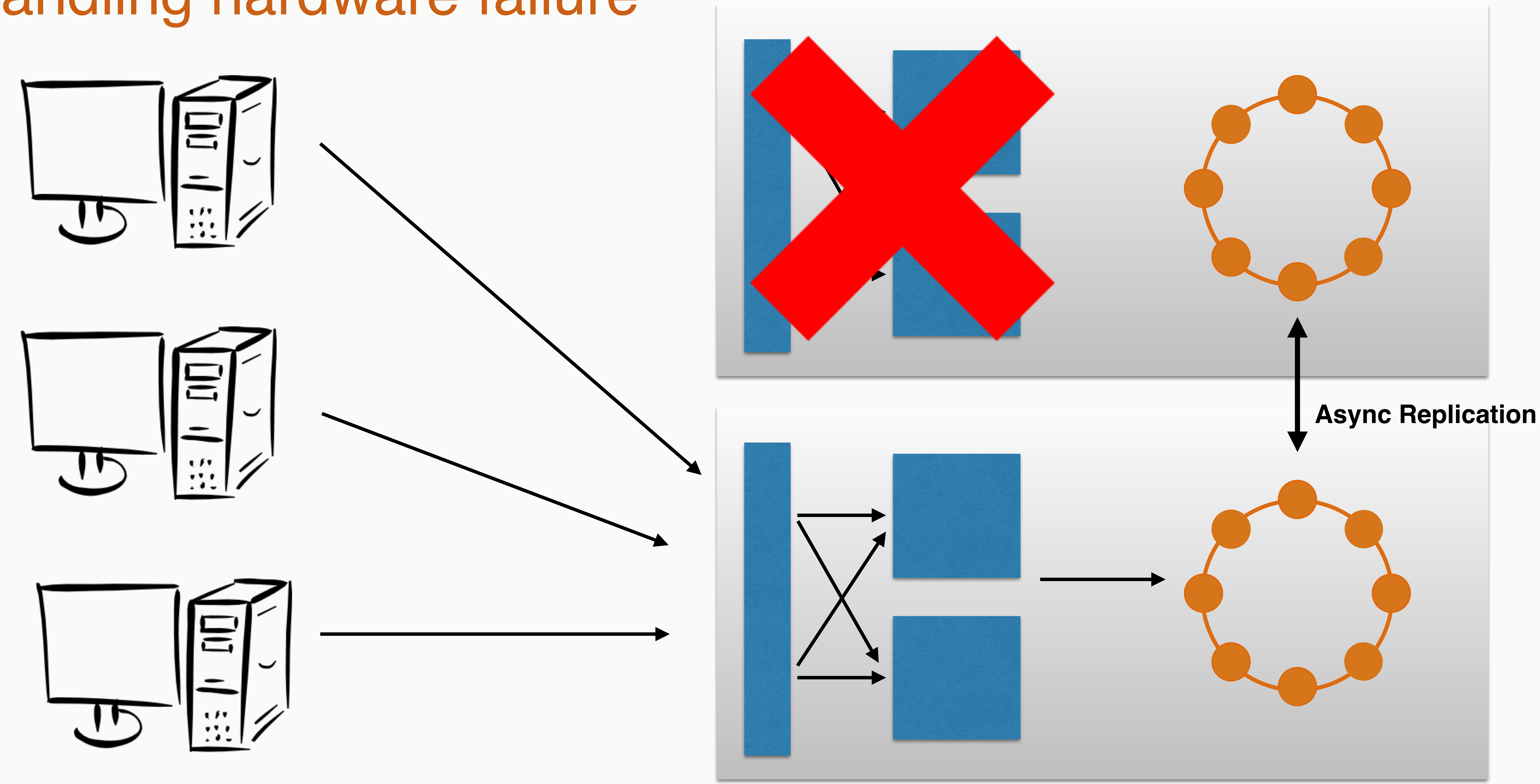

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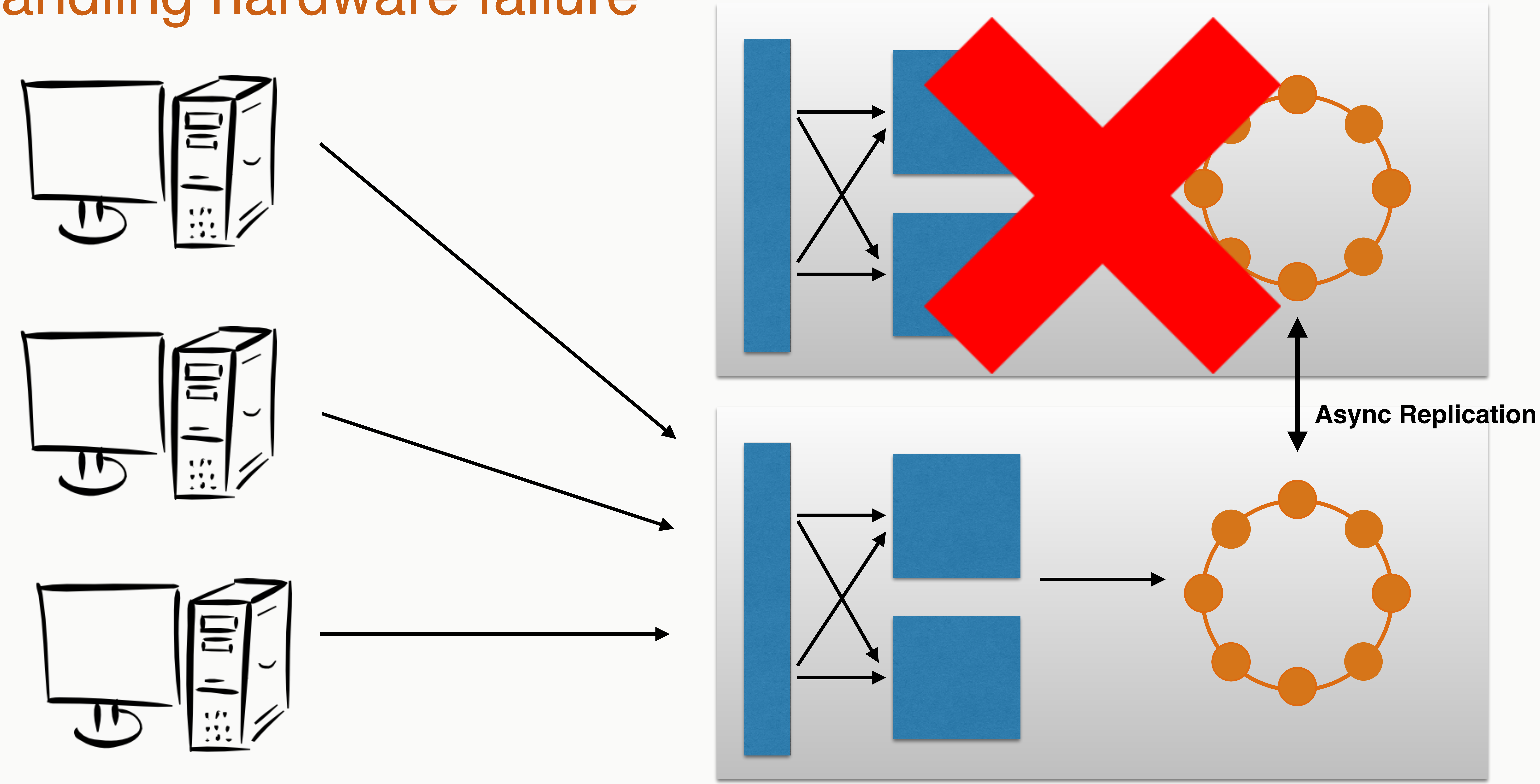
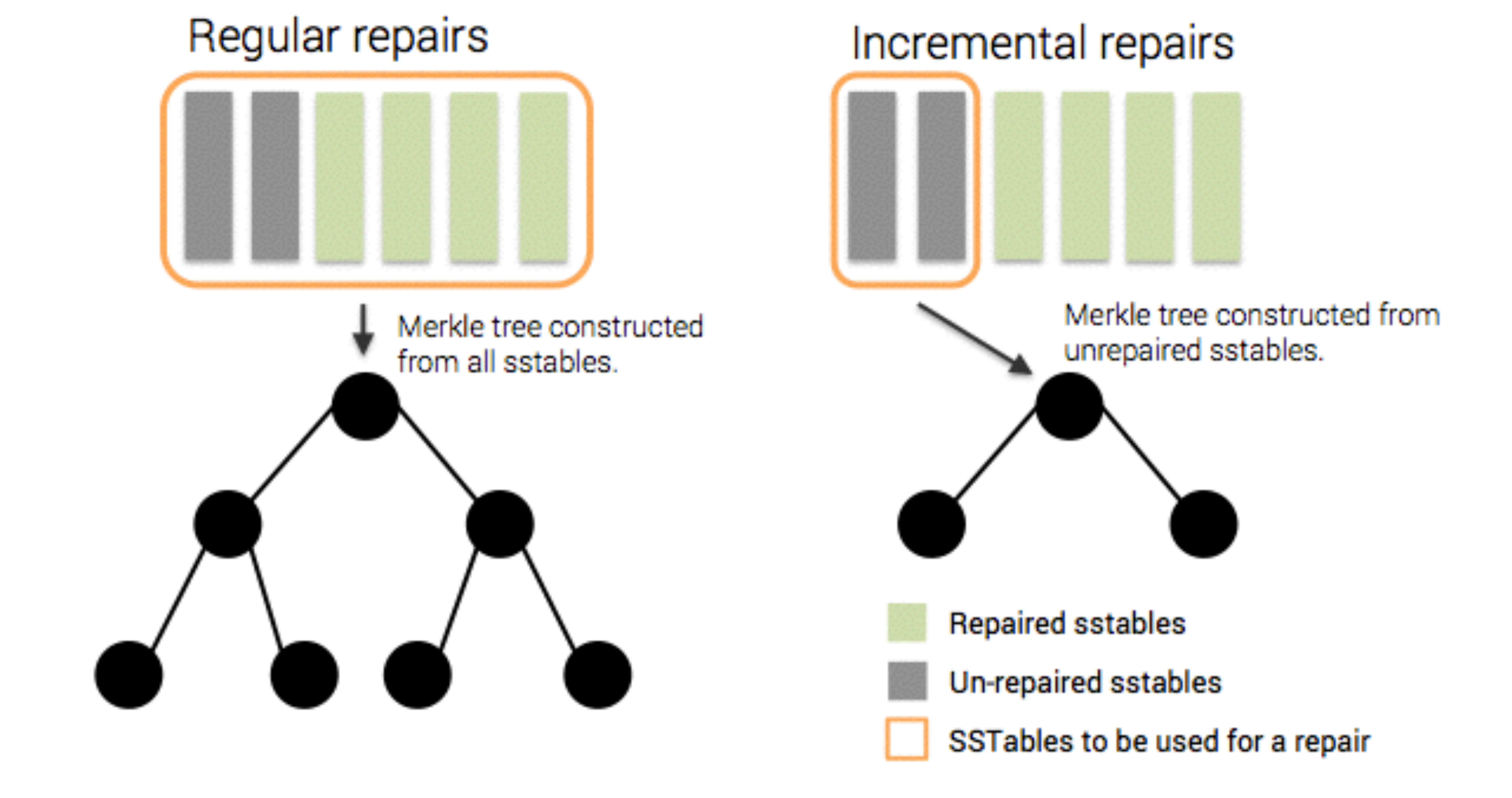


But what happens when they come back?

- Hinted handoff to the rescue
- Coordinators keep writes for downed nodes for a configurable amount of time, default 3 hours
- Longer than that run a repair

Anti entropy repair

- Not exciting but mandatory :)
- New in 2.1 - incremental repair <— awesome



Don’t forget to be social

- Each node talks to a few of its other and shares information

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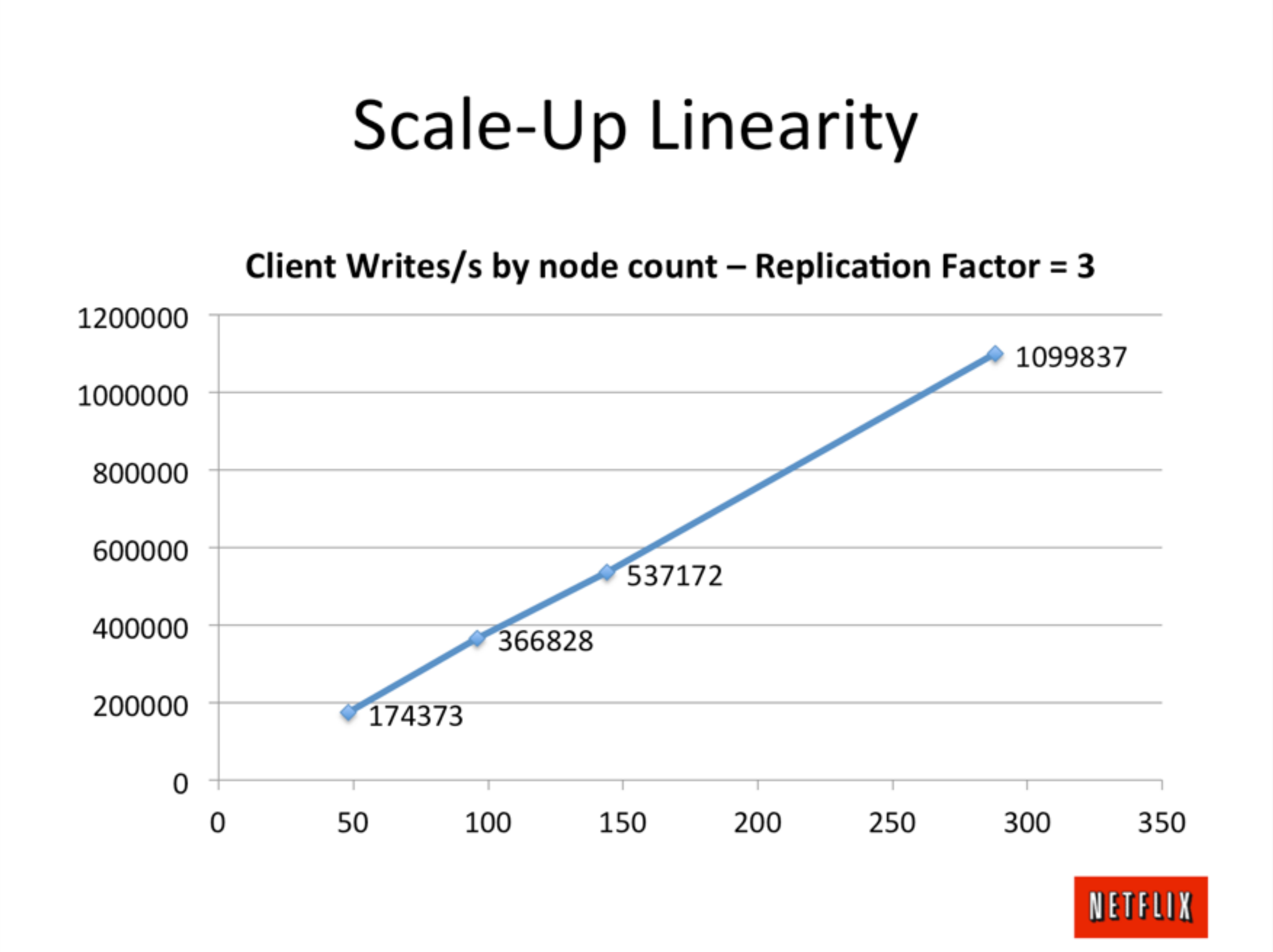
Scaling shouldn't be hard

- Throw more nodes at a cluster
- Bootstrapping + joining the ring
  - For large data sets this can take some time



Data modelling

You must denormalise

CQL

- Cassandra Query Language
  - SQL like query language
- Keyspace – analogous to a schema
  - The keyspace determines the RF (replication factor)
- Table – looks like a SQL Table

```
CREATE TABLE scores (
  name text,
  score int,
  date timestamp,
  PRIMARY KEY (name, score)
);
```

```
INSERT INTO scores (name, score, date)
VALUES ('bob', 42, '2012-06-24');
INSERT INTO scores (name, score, date)
VALUES ('bob', 47, '2012-06-25');
```

```
SELECT date, score FROM scores WHERE name='bob' AND score >= 40;
```

Lots of types

CQL Type	Constants	Description
ascii	strings	US-ASCII character string
bigint	integers	64-bit signed long
blob	blobs	Arbitrary bytes (no validation), expressed as hexadecimal
boolean	booleans	true or false
counter	integers	Distributed counter value (64-bit long)
decimal	integers, floats	Variable-precision decimal
double	integers	64-bit IEEE-754 floating point
float	integers, floats	32-bit IEEE-754 floating point
inet	strings	IP address string in IPv4 or IPv6 format*
int	integers	32-bit signed integer
list	n/a	A collection of one or more ordered elements
map	n/a	A JSON-style array of literals: { literal : literal, literal : literal ... }
set	n/a	A collection of one or more elements
text	strings	UTF-8 encoded string
timestamp	integers, strings	Date plus time, encoded as 8 bytes since epoch
uuid	uuids	A UUID in standard UUID format
timeuuid	uuids	Type 1 UUID only (CQL 3)
varchar	strings	UTF-8 encoded string
varint	integers	Arbitrary-precision integer

UUID

- Universal Unique ID
  - 128 bit number represented in character form e.g. 99051fe9-6a9c-46c2-b949-38ef78858dd0
- Easily generated on the client
  - Version 1 has a timestamp component (TIMEUUID)
  - Version 4 has no timestamp component

TIMEUUID

TIMEUUID data type supports Version 1 UUIDs

Generated using time (60 bits), a clock sequence number (14 bits), and MAC address (48 bits)

- **CQL function 'now()' generates a new TIMEUUID**

Time can be extracted from TIMEUUID

- **CQL function dateOf() extracts the timestamp as a date**

TIMEUUID values in clustering columns or in column names are ordered based on time

- **DESC order on TIMEUUID lists most recent data first**

Collections

```
CREATE TABLE videos (
   videoid uuid,
   userid uuid,
   name varchar,
   description varchar,
   location text,
   location_type int,
   preview_thumbnails map<text,text>,
   tags set<varchar>,
   added_date timestamp,
   PRIMARY KEY (videoid)
);
```

Data Model - User Defined Types

```
CREATE TYPE address (
  street text,
  city text,
  zip_code int,
  country text,
  cross_streets set<text>
);
```

- Complex data in one place
- No multi-gets (multi-partitions)
- Nesting!

Data Model - Updated

- We can embed ***video_metadata*** in ***videos***

```
CREATE TABLE videos (
   videoid uuid,
   userid uuid,
   name varchar,
   description varchar,
   location text,
   location_type int,
   preview_thumbnails map<text,text>,
   tags set<varchar>,
   metadata set <frozen<video_metadata>>,
   added_date timestamp,
   PRIMARY KEY (videoid)
);
```

```
CREATE TYPE video_metadata (
   height int,
   width int,
   video_bit_rate set<text>,
   encoding text
);
```

Data Model - Storing JSON

```
{
   "productId": 2,
   "name": "Kitchen Table",
   "price": 249.99,
   "description" : "Rectangular table with oak finish",
   "dimensions": {
      "units": "inches",
      "length": 50.0,
      "width": 66.0,
      "height": 32
   },
   "categories": {
      {
         "category" : "Home Furnishings" {
            "catalogPage": 45,
            "url": "/home/furnishings"
         },
         {
         "category" : "Kitchen Furnishings" {
            "catalogPage": 108,
            "url": "/kitchen/furnishings"
      }
   }
}
```

```
CREATE TYPE dimensions (
   units text,
   length float,
   width float,
   height float
);

CREATE TYPE category (
   catalogPage int,
   url text
);

CREATE TABLE product (
   productId int,
   name text,
   price float,
   description text,
   dimensions frozen <dimensions>,
   categories map <text, frozen <category>>,
   PRIMARY KEY (productId)
);
```

Tuple type

```
CREATE TABLE tuple_table (
  id int PRIMARY KEY,
  three_tuple frozen <tuple<int, text, float>>,
  four_tuple  frozen <tuple<int, text, float, inet>>,
  five_tuple  frozen <tuple<int, text, float, inet, ascii>>
);
```

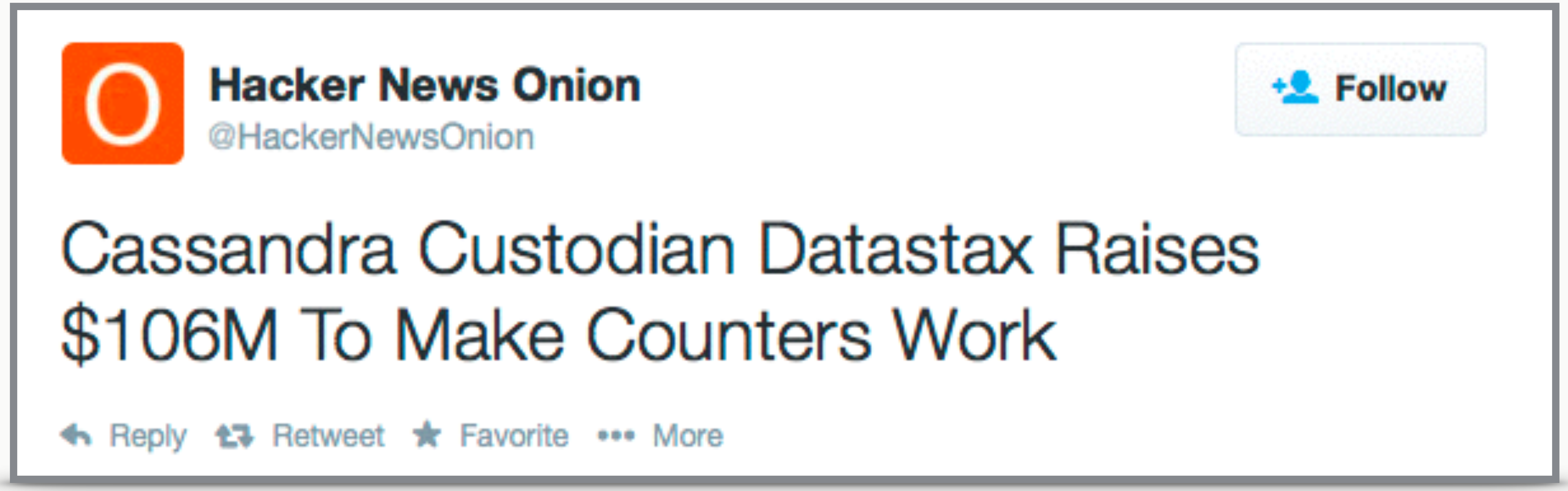
```
cqlsh:killrvideo> INSERT INTO tuple_table (id, three_tuple)
              ... VALUES (1, (1, 'one', 1.0));
```

```
cqlsh:killrvideo> SELECT three_tuple FROM tuple_table WHERE id = 1;

 three_tuple
---------------
 (1, 'one', 1)

(1 rows)
```

- Type to represent a group
- Up to 256 different elements

Counters

- Old has been around since .8
- Commit log replay changes counters
- Repair can change a counter



Time-to-Live (TTL)

TTL a row:

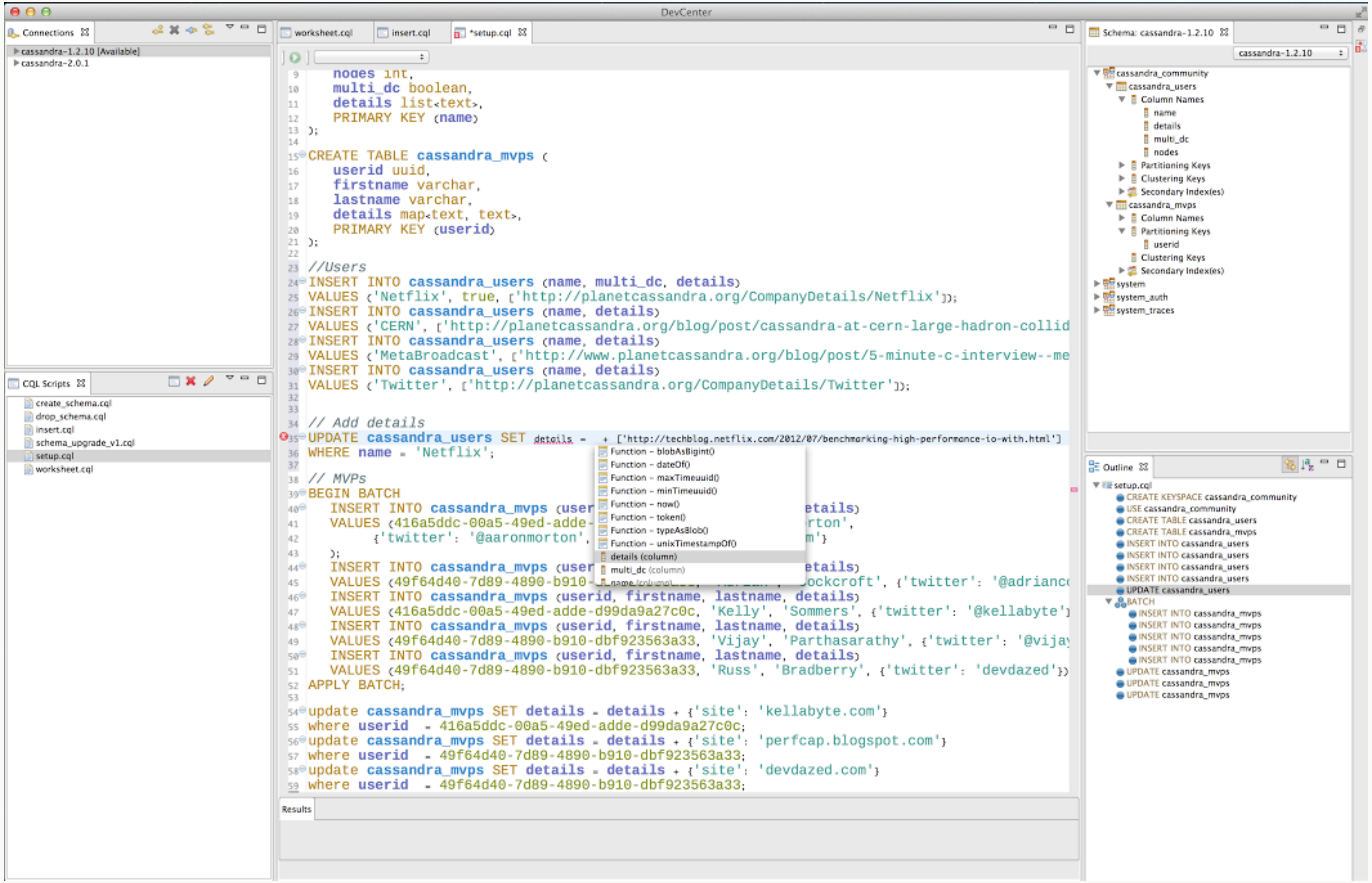
```
INSERT INTO users (id, first, last) VALUES (‘abc123’, ‘catherine’, ‘cachart’)
USING TTL 3600; // Expires data in one hour
```

TTL a column:

```
UPDATE users USING TTL 30 SET last = ‘miller’ WHERE id = ‘abc123’
```

– TTL in seconds
– **Can also set default TTL at a table level**
– Expired columns/values automatically deleted
– With no TTL specified, columns/values never expire
– TTL is useful for automatic deletion
– Re-inserting the same row before it expires will overwrite TTL

DevCenter



Example Time: Customer event store

An example: Customer event store

- Customer event
  - **customer_id** e.g ChrisBatey
  - **event_type** e.g login, logout, add_to_basket, remove_from_basket, buy_item
- Staff
  - **name** e.g Charlie
  - **favourite_colour** e.g red
- Store
  - **name**
  - **type** e.g Website, PhoneApp, Phone, Retail

Requirements

- Get all events
- Get all events for a particular customer
- As above for a time slice

Modelling in a relational database

```
CREATE TABLE customer_events(
    customer_id text,
    staff_name text,
    time timeuuid,
    event_type text,
    store_name text,
    PRIMARY KEY (customer_id));

CREATE TABLE store(
    name text,
    location text,
    store_type text,
    PRIMARY KEY (store_name));

CREATE TABLE staff(
    name text,
    favourite_colour text,
    job_title text,
    PRIMARY KEY (name));
```

Your model should look like your queries

Modelling in Cassandra

```
CREATE TABLE customer_events(
    customer_id text,
    staff_id text,
    time timeuuid,
    store_type text,
    event_type text,
    tags map<text, text>,
    PRIMARY KEY ((customer_id), time));
```

Partition Key

Clustering Column(s)

```
cqlsh:customers> select * from customer_events where customer_id = 'chbatey' and time > minTimeuuid(1) and time < maxTimeuuid(2000000000000) ;

 customer_id | time                                 | event_type | staff_id | store_type | tags
-------------+--------------------------------------+------------+----------+------------+--------------------
     chbatey | 2b329cc0-73f0-11e4-ac06-4b05b98cc84c | basket_add |   trevor |     online | {'item': 'coffee'}
     chbatey | 6a823160-73f0-11e4-ac06-4b05b98cc84c | basket_add |   trevor |     online | {'item': 'coffee'}
```

How it is stored on disk

customer	time	event_type	store_type	tags
charles	2014-11-18 16:52:04	basket_add	online	{'item': 'coffee'}
charles	2014-11-18 16:53:00	basket_add	online	{'item': ‘wine'}
charles	2014-11-18 16:53:09	logout	online	{}
chbatey	2014-11-18 16:52:21	login	online	{}
chbatey	2014-11-18 16:53:21	basket_add	online	{'item': 'coffee'}
chbatey	2014-11-18 16:54:00	basket_add	online	{'item': 'cheese'}

charles	**event_type** basket_add	**staff_id** n/a	**store_type** online	**tags:item** coffee	**event_type** basket_add	**staff_id** n/a	**store_type** online	**tags:item** wine	**event_type** logout	**staff_id** n/a	**store_type** online
chbatey	**event_type** login	**staff_id** n/a	**store_type** online	**event_type** basket_add	**staff_id** n/a	**store_type** online	**tags:item** coffee	**event_type** basket_add	**staff_id** n/a	**store_type** online	**tags:item** cheese

Drivers

Languages

- DataStax (open source)
  - C#, Java, C++, Python, Node, Ruby
  - Very similar programming API
- Other open source
  - Go
  - Clojure
  - Erlang
  - Haskell
  - Many more Java/Python drivers
  - Perl

DataStax Java Driver

- Open source

DataStax Java Driver for Apache Cassandra

A Java client driver for Apache Cassandra. This driver works exclusively with the Cassandra Query Language version 3 (CQL3) and Cassandra's binary protocol.

- JIRA: https://datastax-oss.atlassian.net/browse/JAVA
- MAILING LIST: https://groups.google.com/a/lists.datastax.com/forum/#!forum/java-driver-user
- IRC: #datastax-drivers on irc.freenode.net
- TWITTER: Follow the latest news about DataStax Drivers - @olim7t, @mfiguiere
- DOCS: http://www.datastax.com/documentation/developer/java-driver/2.1/index.html
- API: http://www.datastax.com/drivers/java/2.1
- CHANGELOG: https://github.com/datastax/java-driver/blob/2.1/driver-core/CHANGELOG.rst

The driver architecture is based on layers. At the bottom lies the driver core. This core handles everything related to the connections to a Cassandra cluster (for example, connection pool, discovering new nodes, etc.) and exposes a simple, relatively low-level API on top of which higher level layer can be built.

```
<dependency>
  <groupId>com.datastax.cassandra</groupId>
  <artifactId>cassandra-driver-core</artifactId>
  <version>2.1.2</version>
</dependency>
```

```
<dependency>
  <groupId>com.datastax.cassandra</groupId>
  <artifactId>cassandra-driver-mapping</artifactId>
  <version>2.1.2</version>
</dependency>
```

Get all the events

```
public List<CustomerEvent> getAllCustomerEvents() {
    return session.execute("select * from customers.customer_events")
            .all().stream()
            .map(mapCustomerEvent())
            .collect(Collectors.toList());
}


private Function<Row, CustomerEvent> mapCustomerEvent() {
    return row -> new CustomerEvent(
            row.getString("customer_id"),
            row.getUUID("time"),
            row.getString("staff_id"),
            row.getString("store_type"),
            row.getString("event_type"),
            row.getMap("tags", String.class, String.class));
}
```

All events for a particular customer

```
private PreparedStatement getEventsForCustomer;

@PostConstruct
public void prepareSatements() {
    getEventsForCustomer =
     session.prepare("select * from customers.customer_events where customer_id = ?");
}

public List<CustomerEvent> getCustomerEvents(String customerId) {
    BoundStatement boundStatement = getEventsForCustomer.bind(customerId);
    return session.execute(boundStatement)
            .all().stream()
            .map(mapCustomerEvent())
            .collect(Collectors.toList());
}
```

Customer events for a time slice

```java
public List<CustomerEvent> getCustomerEventsForTime(String customerId, long startTime,
long endTime) {

    Select.Where getCustomers = QueryBuilder.select()
            .all()
            .from("customers", "customer_events")
            .where(eq("customer_id", customerId))
            .and(gt("time", UUIDs.startOf(startTime)))
            .and(lt("time", UUIDs.endOf(endTime)));


    return session.execute(getCustomers).all().stream()
            .map(mapCustomerEvent())
            .collect(Collectors.toList());
}
```

Mapping API

```java
@Table(keyspace = "customers", name = "customer_events")
public class CustomerEvent {
    @PartitionKey
    @Column(name = "customer_id")
    private String customerId;

    @ClusteringColumn
    private UUID time;

    @Column(name = "staff_id")
    private String staffId;

    @Column(name = "store_type")
    private String storeType;

    @Column(name = "event_type")
    private String eventType;

    private Map<String, String> tags;
    // ctr / getters etc
}
```

Mapping API

```
@Accessor
public interface CustomerEventDao {
    @Query("select * from customers.customer_events where customer_id = :customerId")
    Result<CustomerEvent> getCustomerEvents(String customerId);

    @Query("select * from customers.customer_events")
    Result<CustomerEvent> getAllCustomerEvents();

    @Query("select * from customers.customer_events where customer_id = :customerId
and time > minTimeuuid(:startTime) and time < maxTimeuuid(:endTime)")
    Result<CustomerEvent> getCustomerEventsForTime(String customerId, long startTime,
long endTime);
}


@Bean
public CustomerEventDao customerEventDao() {
    MappingManager mappingManager = new MappingManager(session);
    return mappingManager.createAccessor(CustomerEventDao.class);
}
```

Adding some type safety

```java
public enum StoreType {
    ONLINE, RETAIL, FRANCHISE, MOBILE
}
```

```java
@Table(keyspace = "customers", name = "customer_events")
public class CustomerEvent {
    @PartitionKey
    @Column(name = "customer_id")
    private String customerId;

    @ClusteringColumn()
    private UUID time;

    @Column(name = "staff_id")
    private String staffId;

    @Column(name = "store_type")
    @Enumerated(EnumType.STRING) // could be EnumType.ORDINAL
    private StoreType storeType;
```

User defined types

```
create TYPE store (name text, type text, postcode text) ;


CREATE TABLE customer_events_type(
 customer_id text,
 staff_id text,
 time timeuuid,
 store frozen<store>,
 event_type text,
 tags map<text, text>,
 PRIMARY KEY ((customer_id), time));
```

Mapping user defined types

```
@UDT(keyspace = "customers", name = "store")
public class Store {
    private String name;
    private StoreType type;
    private String postcode;
    // getters etc
 }

@Table(keyspace = "customers", name = "customer_events_type")
public class CustomerEventType {
    @PartitionKey
    @Column(name = "customer_id")
    private String customerId;

    @ClusteringColumn()
    private UUID time;

    @Column(name = "staff_id")
    private String staffId;

    @Frozen
    private Store store;

    @Column(name = "event_type")
    private String eventType;

    private Map<String, String> tags;
```

Mapping user defined types

```java
@UDT(keyspace = "customers", name = "store")
public class Store {
    private String name;
    private StoreType type;
    private String postcode;
    // getters etc
 }

@Table(keyspace = "customers", name = "customer_events_type")
public class CustomerEventType {
    @PartitionKey
    @Column(name = "customer_id")
    private String customerId;

    @ClusteringColumn()
    private UUID time;

    @Column(name = "staff_id")
    private String staffId;

    @Frozen
    private Store store;

    @Column(name = "event_type")
    private String eventType;

    private Map<String, String> tags;
```

```java
@Query("select * from customers.customer_events_type")
Result<CustomerEventType> getAllCustomerEventsWithStoreType();
```

DATASTAX

Other features

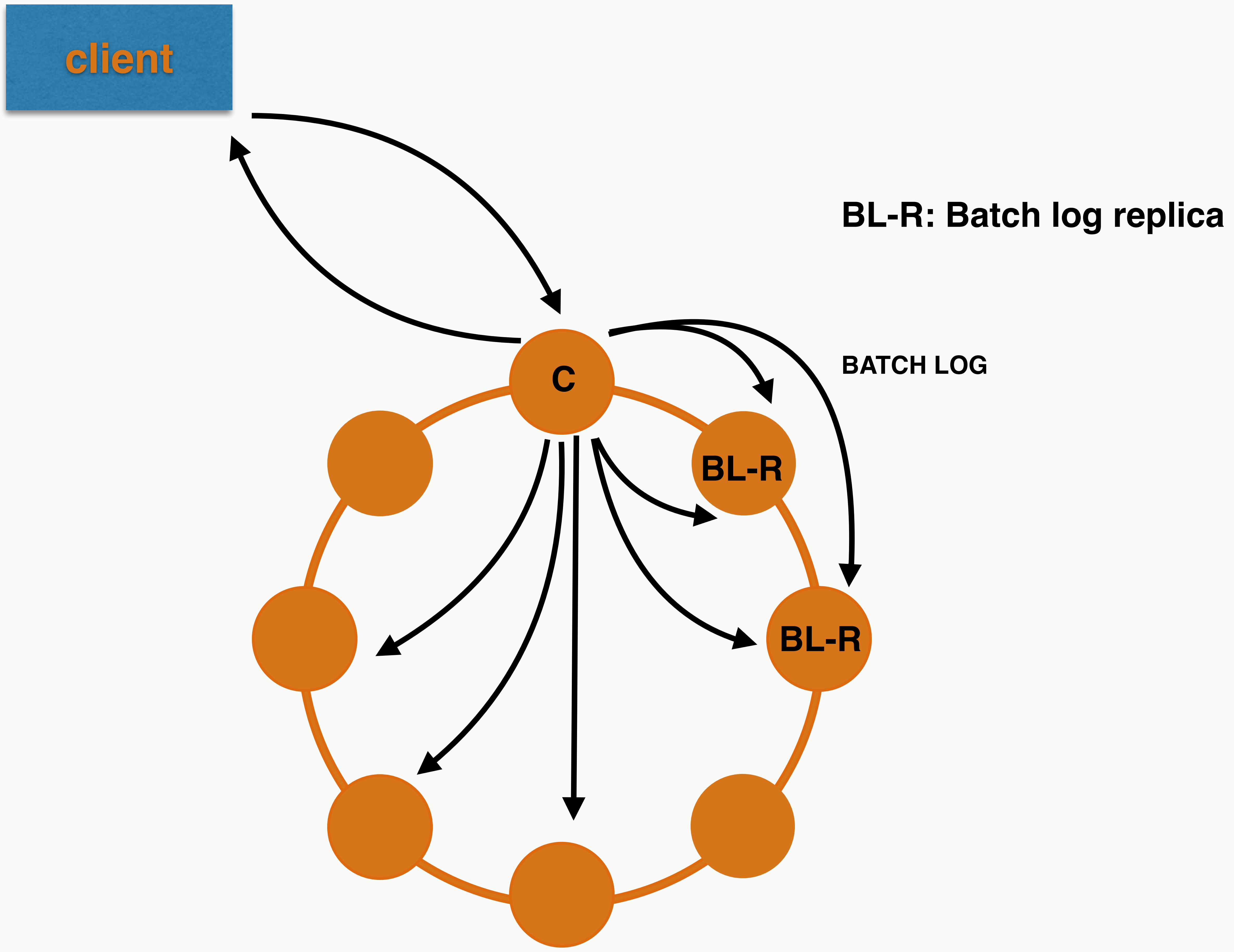
Query Tracing

```
Connected to cluster: xerxes
Simplex keyspace and schema created.
Host (queried): /127.0.0.1
Host (tried): /127.0.0.1
Trace id: 96ac9400-a3a5-11e2-96a9-4db56cdc5fe7

activity                               | timestamp    | source     | source_elapsed
---------------------------------------+--------------+------------+--------------
                     Parsing statement | 12:17:16.736 | /127.0.0.1 |            28
                    Peparing statement | 12:17:16.736 | /127.0.0.1 |           199
    Determining replicas for mutation | 12:17:16.736 | /127.0.0.1 |           348
        Sending message to /127.0.0.3 | 12:17:16.736 | /127.0.0.1 |           788
        Sending message to /127.0.0.2 | 12:17:16.736 | /127.0.0.1 |           805
       Acquiring switchLock read lock | 12:17:16.736 | /127.0.0.1 |           828
               Appending to commitlog | 12:17:16.736 | /127.0.0.1 |           848
             Adding to songs memtable | 12:17:16.736 | /127.0.0.1 |           900
     Message received from /127.0.0.1 | 12:17:16.737 | /127.0.0.2 |            34
     Message received from /127.0.0.1 | 12:17:16.737 | /127.0.0.3 |            25
       Acquiring switchLock read lock | 12:17:16.737 | /127.0.0.2 |           672
       Acquiring switchLock read lock | 12:17:16.737 | /127.0.0.3 |           525
```

Storing events to both tables in a batch

```
public void storeEventLogged(CustomerEvent customerEvent) {
    BoundStatement boundInsertForCustomerId = insertByCustomerId.bind(customerEvent.getCustomerId(),
       customerEvent.getTime(),
       customerEvent.getEventType(),
       customerEvent.getStaffId(),
       customerEvent.getStaffId());

    BoundStatement boundInsertForStaffId = insertByStaffId.bind(customerEvent.getCustomerId(),
       customerEvent.getTime(),
       customerEvent.getEventType(),
       customerEvent.getStaffId(),
       customerEvent.getStaffId());

    BatchStatement batchStatement = new BatchStatement(BatchStatement.Type.LOGGED);
    batchStatement.add(boundInsertForCustomerId);
    batchStatement.add(boundInsertForStaffId);

    session.execute(batchStatement);
}
```

Why is this slower?



Light weight transactions

- Often referred to as compare and set (CAS)

```
INSERT INTO STAFF (login, email, name)
values ('chbatey', ‘christopher.batey@datastax.com', ‘Chirstopher Batey')
IF NOT EXISTS
```

Summary

- Cassandra is a shared nothing masterless datastore
- Availability a.k.a up time is king
- Biggest hurdle is learning to model differently
- Modern drivers make it easy to work with

Thanks for listening

- Follow me on twitter @chbatey
- Cassandra + Fault tolerance posts a plenty:
  - http://christopher-batey.blogspot.co.uk/
- Cassandra resources: http://planetcassandra.org/
- Full free day of Cassandra talks/training:
  - http://www.eventbrite.com/e/cassandra-day-london-2015-april-22nd-2015-tickets-15053026006?aff=meetup1